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Telecom Sector Skill Council

Participant Handbook

Sector
Telecom

Sub-Sector
Network Managed Services

Occupation
Network Operation and Maintenance

Reference ID: **TEL/Q6207,** Version **5.0**
NSQF Level **4**

Optical Network Terminal Technician

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Shri Narendra Modi
Prime Minister of India

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TELECOM SECTOR SKILL COUNCIL

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The preparation of this handbook would not have been possible without the Telecom Industry's support. Industry feedback has been extremely encouraging from inception to conclusion and it is with their input that we have tried to bridge the skill gaps existing today in the industry.

This participant handbook is dedicated to the aspiring youth who desire to achieve special skills which will be a lifelong asset for their future endeavours.

About this book

India is currently the world's second-largest telecommunications market, with a total subscriber base of approximately 1.188 billion as of October 2024. As of June 30, 2025, the total number of telephone subscribers reached 1.218 billion, with wireless (mobile plus 5G FWA) subscriptions at 1.171 billion, illustrating continued robust growth.

Over the past decade and a half, the telecom industry has witnessed exponential expansion. Internet (broadband) connections surged nearly 386 million between March 2014 and June 2024, while broadband connections themselves grew more than fourteenfold. This surge reflects not only growth in subscriber numbers but also dramatic improvements in access and service affordability.

The telecom sector has been instrumental in India's socioeconomic development—playing a key role in bridging the rural–urban digital divide, enhancing connectivity, and fueling digital inclusion.

According to data from around 2020–2021, the industry contributed about 6% of India's GDP and supported 2.2 million direct jobs and 1.8 million indirect jobs. While more recent estimates on GDP contribution specifically from telecom aren't available, the broader ICT and digital economy sector contributes over 13% of India's GDP, underscoring the telecom sector's growing economic significance.

Looking ahead, India's upcoming National Telecom Policy (NTP) aims to further catalyze growth. Among its goals are doubling telecom exports, achieving universal affordable connectivity through terrestrial and satellite networks, and creating one million new jobs by 2030. The policy also seeks to increase the telecom sector's GDP share from around 7.8% to 11% by 2030 and attract ₹1.5 lakh crore annually in telecom infrastructure investment.

This Participant Handbook delivers both theoretical knowledge and practical skill training for aspiring Optical Network Terminal Technicians in the telecom sector.

Key responsibilities include:

- Ensure continuous 24x7 operation of Optical Network Terminal (ONT) sites by performing routine maintenance and basic fault repair.
- Maintain site security and hygiene by following standard safety practices and ensuring a clean, safe working environment (TEL/N6226).
- Conduct preventive maintenance of ONT components to prevent service disruptions and improve system reliability (TEL/N6227).
- Troubleshoot and resolve basic technical faults at ONT sites in a timely and effective manner.
- Promote digital adoption by educating local customers on the use of telecom devices and services, highlighting the Features, Advantages, and Benefits.
- Engage walk-in customers at the site or service center by allowing hands-on experience with devices and addressing queries on telecom products and services.
- Apply sustainable practices in telecom infrastructure management to minimize environmental impact and promote energy efficiency.
- Communicate effectively with customers and team members, applying problem-solving skills under pressure to resolve issues.
- Demonstrate professionalism, self-discipline, and teamwork while ensuring high-quality service delivery.

Aligned with the latest and approved version of Optical Network Terminal Technician (TEL/Q6207), the handbook includes the following National Occupational Standards (NOSs):

1. TEL/N6226: Maintain Site Security and Hygiene
2. TEL/N6227: Perform Preventive Maintenance of Optical Network Terminal (ONT) Components
3. TEL/N6228: Promote use of Devices and Provide Services
4. TEL/N9109: Follow sustainable practices in telecom infrastructure management
5. DGT/VSQ/N0101: Employability Skills (30 Hours)

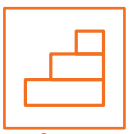
Upon completion, participants will be equipped to:

- Maintain and ensure continuous operation of ONT sites, including performing preventive maintenance, troubleshooting, and basic fault repair.
- Apply site security and hygiene practices to maintain safe and clean working environments.
- Promote telecom devices and services by effectively communicating their Features, Advantages, and Benefits (FAB) to customers.
- Engage and educate customers to promote digital adoption and enhance their telecom experience.
- Apply sustainable practices to manage telecom infrastructure efficiently.
- Handle customer queries with confidence and professionalism, ensuring high customer satisfaction.
- Demonstrate strong analytical, communication, and problem-solving skills while working under pressure.
- Collaborate effectively as part of a team, contributing proactively to achieving operational goals.
- Exhibit self-discipline, time management, and workplace ethics in day-to-day operations.

We trust this Participant Handbook will offer strong learning support and help budding professionals carve out engaging and rewarding careers in India's dynamic telecom industry.

Symbols Used


Key Learning Outcomes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1. Role and Responsibilities of an Optical Network Terminal Technician

Telecom Sector Skill Council

TEL/N6226

Key Learning Outcomes

By the end of this module, the paricipants will be able to:

1. Explain the history and evolution of the telecom industry.
2. Describe different types of communication systems used in telecommunications.
3. Identify and compare various transmission media and their applications.
4. Analyze the growth and development of the telecom sector in India.
5. Explain the key aspects of the Electromagnetic Spectrum and its significance in telecommunications.
6. Describe the features and properties of electromagnetic waves.
7. Elaborate on the key regions of the Electromagnetic Spectrum and their specific functions in communication.
8. Provide an overview of mobile communication technologies and their evolution.
9. Explain the need for fiber-optic communication in modern telecom networks.
10. Describe the architecture and working principles of optical communication systems.
11. Explain how optical fibers function as a communication channel, including their advantages and limitations.
12. Describe the working of optical transmitters and receivers, and their role in optical communication systems.

UNIT 1.1: Introduction to Telecommunications

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the history and evolution of the telecom industry.
2. Describe the different types of communication systems and their applications.
3. Identify and compare various transmission media used in telecommunications

1.1.1 History of Telecom

The history of telecommunications dates back to the late 19th century. In 1880, scientists Alexander Graham Bell and Charles Sumner Tainter conducted the first wireless telephone call using a modulated light beam, an early experiment in optical communication. However, practical applications of this technology were not widely implemented until much later, notably in military systems and eventually in fiber-optic communications.

Here is a chronological overview of key milestones in the evolution of communications and telecommunications:

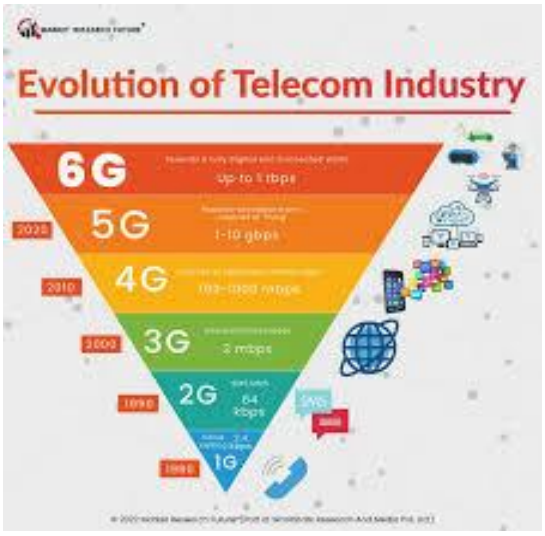

Fig 1.1.1 Evolution of Telecom Industry

Here is a chronological overview of key milestones in the evolution of communications and telecommunications:

- **1672:** First experimental acoustic (mechanical) telephone.
- **1790:** Semaphore lines (optical telegraphs) used for visual signaling.
- **1838:** Invention of the electr3ical telegraph by Cooke and Wheatstone.
- **1858:** First transatlantic telegraph cable laid, enabling global telegraphic communication.
- **1876:** Alexander Graham Bell invented the telephone.
- **1877:** Acoustic phonograph invented.
- **1893:** Wireless telegraphy (radio signals) first demonstrated.
- **1914:** Intercontinental telephone communication established.
- **1927:** Development of television and the first commercial radiotelephone

- **1930:** First experimental videophones demonstrated.
- **1936:** First public video-phone network established in the world.
- **1946:** Mobile telephone service introduced for automobiles, albeit with limited capacity.
- **1956:** First transatlantic telephone cable (TAT-1) installed.
- **1964:** Introduction of fiber-optic telecommunications, using light to transmit data over long distances.
- **1965:** First North American public video-phone network launched.
- **1969:** Birth of computer networking, leading to the early foundation of the internet.
- **1973:** Martin Cooper of Motorola demonstrated the first modern-era handheld mobile phone.
- **1979:** INMARSAT satellite communication system launched for ship-to-shore communications.
- **1981:** Introduction of the first digital cellular mobile phone network.
- **1982:** Introduction of email as an additional communication service.
- **1983:** Commercial Internet services began, revolutionizing global connectivity.
- **1998:** Launch of mobile satellite handheld phones for global communication.
- **2003:** Emergence of VoIP (Voice over Internet Protocol) as a popular Internet telephony solution.

1.1.2 Basics of Communication Systems

Communication is the process of exchanging information between two or more parties, persons, or nodes. The primary goal of any communication system is to enable fast, reliable, and efficient exchange of information such as voice, SMS, video, text, music, and live sessions between two points.

A typical communication system consists of:

- **Transmitter:** Converts the original information (voice, text, video, etc.) into signals suitable for transmission.
- **Channel:** The medium through which the signal travels — this can be wired (copper, fiber optics) or wireless (radio waves, microwaves).
- **Receiver:** Receives the transmitted signal and converts it back into the original information.

Information is often susceptible to noise (unwanted interference), which can distort the signal during transmission.

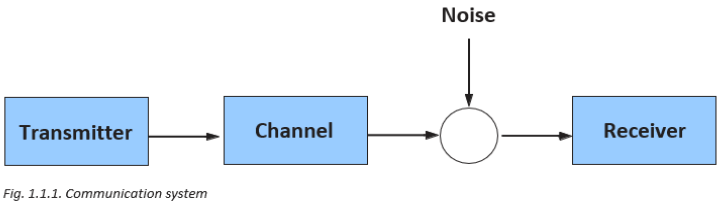

Fig. 1.1.1. Communication system

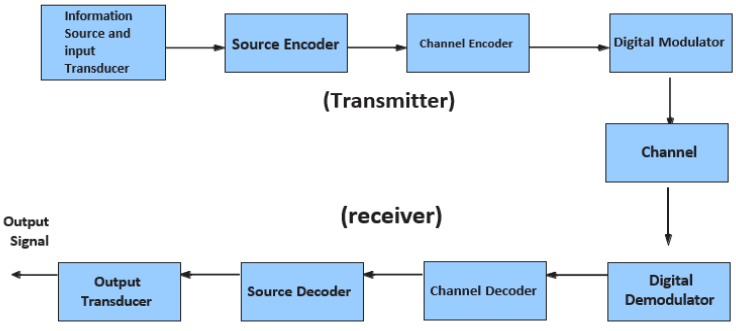

Fig. 1.1.2. Communication system

Communication Process Overview:

- Initial information (voice, SMS, text, video, live session) is analog and can travel only short distances.
- To improve security and distance of transmission, the information is encoded (source coding and channel coding) and modulated before transmission.
- At the receiver end, the signal passes through a demodulator, channel decoder, and source decoder to retrieve the original information.

Types of Communication Media:

- **Wired Media:** Involves physical cables such as twisted pair, coaxial cables, and optical fiber.
- **Wireless Media:** Uses electromagnetic waves (radio, microwave, infrared) to transmit data without physical connections.

1.1.3 Types of Communication Systems

1. **Simplex System**

   Simplex communication allows data to flow in only one direction.

   Example: A traditional television broadcast where the station transmits content and viewers only receive it.

2. **Half-Duplex System**

   Half-duplex allows communication in both directions, but not simultaneously — only one party transmits at a time.

   Example: Walkie-talkies operate in half-duplex mode where a user must press a "push-to-talk" button to speak.

3. **Full-Duplex System**

   Full-duplex enables simultaneous two-way communication between both parties.

   Example: Landline telephones and modern mobile phones allow both participants to speak and listen at the same time.

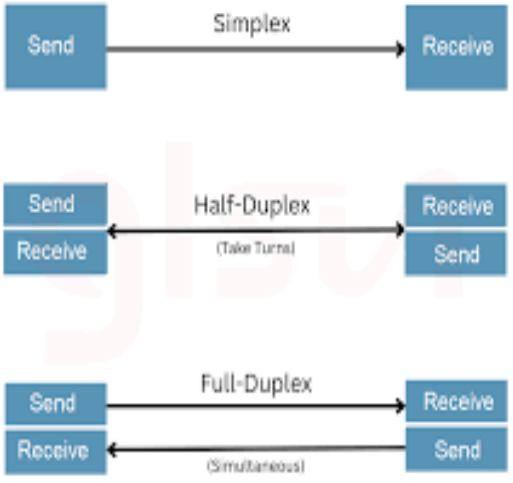

Fig 1.1.3.Communication systems

1.1.4 Transmission Media / Channel

The Transmission Media is the physical or wireless channel used for transferring information from transmitter to receiver.

1. **Bounded Media (Wired Media):**
    - Twisted Pair Cable: Commonly used for telephone networks and local area networks (LAN).
    - Coaxial Cable: Used for cable television and broadband internet.
    - Optical Fiber: Uses light to transmit data at high speed and over long distances, with low signal loss.

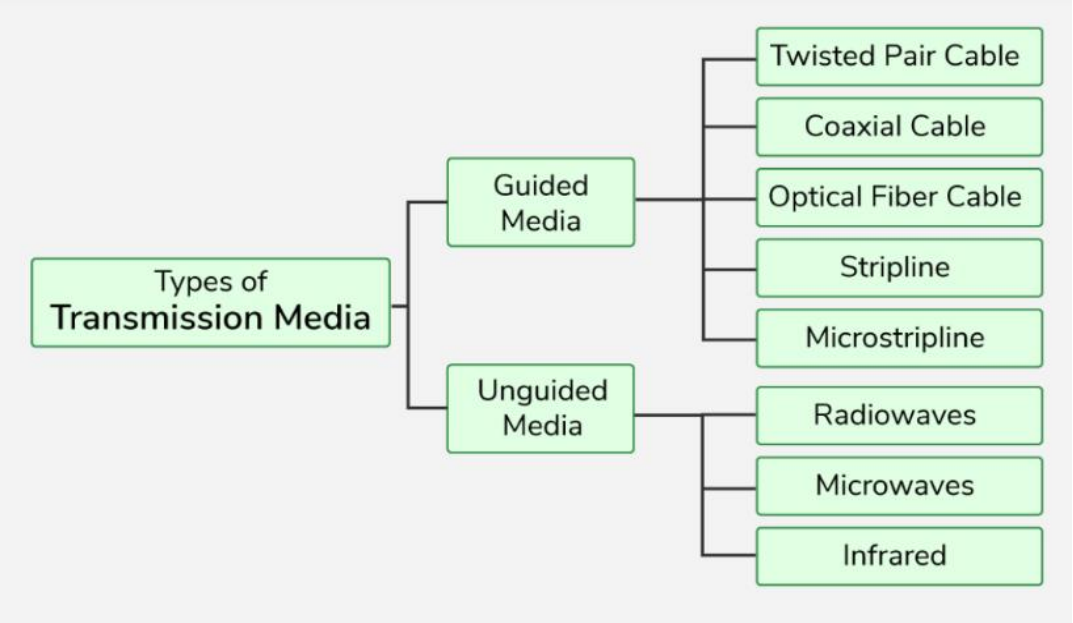

Fig. 1.1.4 Types of Transmission Media

2. **Unbounded Media (Wireless Media)**
    - **Radio Transmission:** Uses radio waves to transmit signals over the air.
    - **Microwave Transmission:** High-frequency transmission often used for point-to-point communication links.
    - **Satellite Communication:** Enables global coverage for data transmission, especially in remote areas

Notes

UNIT 1.2: Industry Outlook – Global & National

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the growth of the telecom industry in India

1.2.1 Telecom Growth in India

India stands as the second-largest telecommunications market globally, following China, in terms of commercial scale and subscriber base. As of March 2025, India boasts a total of 1.2 billion telephone subscribers, with 1.16 billion wireless subscribers and 37 million wireline subscribers.

The nation's internet user base has witnessed remarkable growth, reaching 821 million active internet users by the end of 2023. Notably, rural India accounts for a significant portion of this increase, with over half of the internet users residing in rural areas.

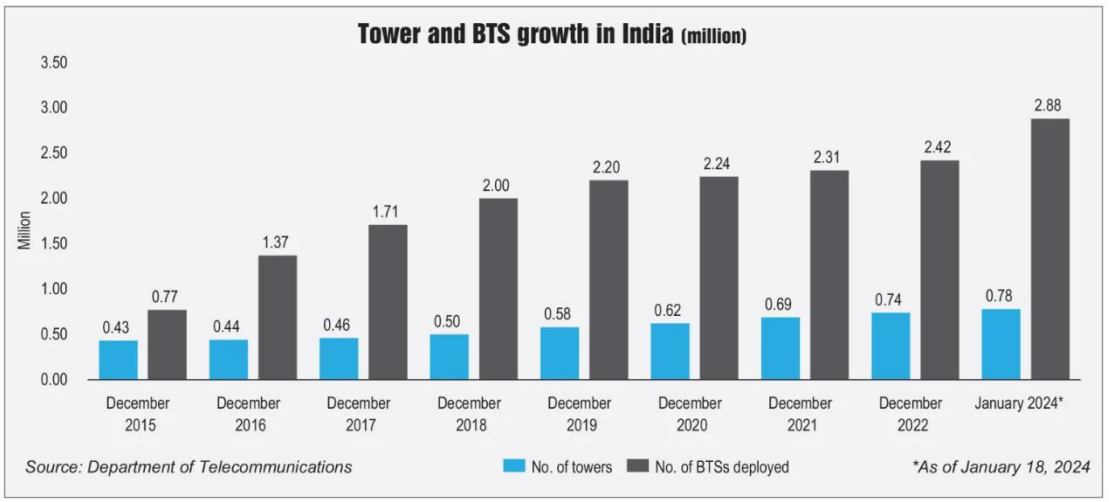

Fig. 1.2.1 Telecom growth in India

The proliferation of 4G networks, now covering 95% of the population, has been instrumental in this digital expansion. Additionally, 5G adoption is accelerating, with 365 million 5G subscribers reported as of July 2025, marking a 35% penetration rate just three years post-launch.

India's broadband infrastructure has also seen substantial growth. As of December 2023, the country had 832 million broadband connections, comprising 799 million wireless and 32 million wireline connections.

The competitive landscape among telecom operators has driven some of the lowest call tariffs globally, fostering widespread adoption of mobile and internet services. This dynamic environment has positioned India as a leading player in the global telecom sector.

1.2.2 Key Statistics – Telecom Industry in India (As of 2025)

Sector	Data
Total Telephone Subscribers	1.2 billion (March 2025)
Mobile Subscribers	1.16 billion (March 2025)
Fixed Line Subscribers	37 million (March 2025)
Internet Users	821 million (end of 2023)
Broadband Connections	832 million (December 2023)
5G Subscribers	365 million (July 2025)
4G Network Coverage	95% of the population (June 2024)

1.2.3 International Telecommunication Union (ITU)

The International Telecommunication Union (ITU) continues to play a pivotal role in the global telecom landscape. As a specialized agency of the United Nations, the ITU coordinates the shared global use of the radio spectrum, promotes international cooperation in assigning satellite orbits, and works to improve telecommunication infrastructure in the developing world.

The ITU is actively involved in areas such as:

- Broadband Internet
- Next-generation wireless technologies
- Aeronautical and maritime navigation
- Radio astronomy
- Satellite-based meteorology
- Convergence of fixed-mobile networks
- Internet access, data, voice, and TV broadcasting
- Development of future telecom networks

Additionally, the ITU organizes global and regional exhibitions and forums, such as ITU TELECOM WORLD, bringing together governments, industry experts, and ICT representatives to share knowledge, technology innovations, and regulatory insights.

Headquartered in Geneva, Switzerland, the ITU operates as an intergovernmental public-private partnership organization and is part of the United Nations Development Group (UNDG).

Notes

UNIT 1.3: Responsibilities of an Optical Network Terminal Technician

Unit Objectives

By the end of this unit, the participants will be able to:

1. Describe the roles and responsibilities of an Optical Network Terminal (ONT) Technician.
2. Discuss organizational policies relevant to an Optical Network Terminal (ONT) Technician.
3. Identify the standard checklists and schedules recommended by Operating Companies (OPCOs).

1.3.1 Role of an Optical Network Terminal (ONT) Technician

An Optical Network Terminal (ONT) Technician plays a critical role in ensuring the seamless operation of Optical Network Terminal (ONT) sites at the local level. The primary responsibilities include:

- Ensuring 24x7 functionality of ONT sites by performing routine maintenance and basic fault repairs.
- Troubleshooting and resolving minor technical issues at the ONT site to prevent service disruptions.
- Promoting digital adoption among local populations by educating them about telecom devices and services.

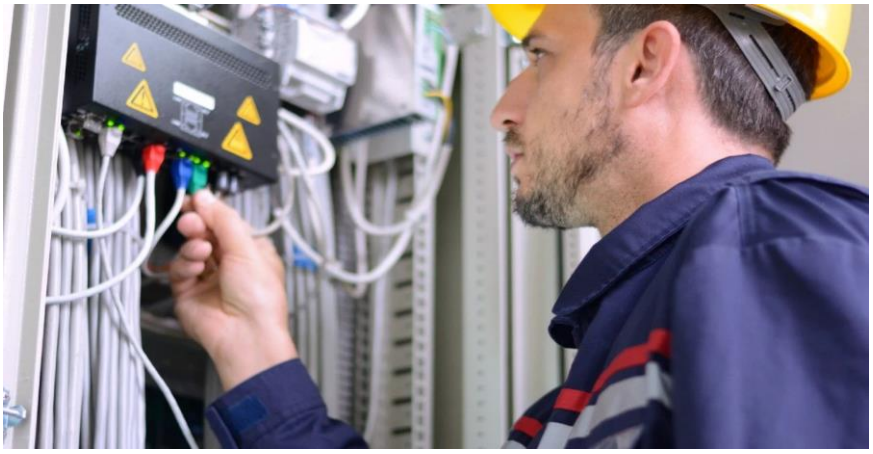

Fig. 1.3.1 ONT Technician

Key Competencies of an ONT Technician:

1. Technical Understanding:

- Operation of critical equipment such as CCU (Central Control Unit), SPV (Single Point of Visibility), TJB (Termination Junction Box), battery banks, and fire extinguishers.
- Proficiency in using laptops, smartphones, tablets, and other electronic diagnostic devices.
- Knowledge of cable infrastructure, UPS systems, and general electrical devices.
- Understanding of pigtails, patch cords, and basic electrical wiring principles.

2. **Problem Solving:**
   - Ability to apply FAQ guidelines to troubleshoot common ONT issues.
   - Basic knowledge of software and hardware configurations for resolving faults.

1.3.2 Character Traits of an ONT Technician

An effective ONT Technician should be:

- Technically qualified
- Self-disciplined
- Assertive
- Action-oriented
- A team player
- Analytical in thinking
- Solution-focused
- Equipped with effective communication skills
- Capable of working efficiently under pressure
- Results-driven

Health & Safety Considerations

This role carries occupational risks such as:

- Exposure to electric shocks
- Cuts, abrasions, and wounds
- Backaches due to physical work
- Contact with sharp tools and hardware components

Adherence to safety standards, PPE use, and careful handling of tools and electrical equipment are mandatory.

1.3.3 Career Progression Pathway

With over 1.2 billion telecom subscribers in India (growing by 12–15 million per month), the telecom industry remains one of the fastest-growing sectors.

Newer technologies like 5G, IoT, and cloud computing are driving demand for skilled ONT Technicians, opening career opportunities in both hardware and software domains.

Career progression may lead to roles such as:

- Senior ONT Technician
- Field Service Engineer
- Network Operations Center (NOC) Technician
- Technical Support Engineer

1.3.4 Organizational Policies

Incentives:

- Employees are rewarded based on performance to encourage higher productivity and quality service delivery.
- Incentives vary based on the company's culture and individual performance.
- Well-structured incentive plans are linked directly to key performance indicators (KPIs).
- Benefits could include monetary bonuses, recognition awards, and career advancement opportunities.

Delivery Standards:

- Defined protocols ensure consistent service quality.
- Adherence to predefined maintenance schedules and checklists ensures optimal ONT performance and customer satisfaction.

Personnel Management:

- Personnel management ensures the right mix of talent, knowledge, and performance in alignment with business goals.

Key functions include:

- Organizational Planning and Development
- Staffing and Employment
- Training and Development
- Compensation and Benefits
- Employee Records
- Labour Relations and Personnel Audits

Public Relations (PR)

PR helps safeguard the organization’s reputation by promoting positive public perception.

Key benefits include:

- Enhanced credibility through independent sources
- Greater readership than paid advertisements
- More detailed and trustworthy information about services
- Cost-effective compared to paid advertising
- Speed in disseminating important updates

1.3.5 Optical Network Terminal (ONT)

An Optical Network Terminal (ONT) is a device that serves as a fiber-optic internet outlet, similar to how a cable modem acts as a coaxial cable internet outlet. It is the end-user device in a Passive Optical Network (PON) that connects a home or business directly to an Internet Service Provider (ISP).

- **Function:** An ONT converts optical signals (light pulses) from the fiber-optic network into electrical signals (Ethernet) that your router can use. It is a critical component for delivering fiber-optic internet service.
- **Location:** The ONT is installed at the user's premises, often at a "Termination Point" (TP) where the external fiber-optic line enters the building.
- **Connectivity:** The ONT connects to the ISP's network via an optical fiber cable. It then connects to a router (often a "fiber router" or gateway) using a standard Ethernet cable (LAN cable), which then distributes the internet connection to your devices via Wi-Fi or wired connections.

ONT vs. ONU

The terms Optical Network Terminal (ONT) and Optical Network Unit (ONU) are often used interchangeably, but there is a slight distinction based on industry standards and physical location.

- **ONT:** This is the term used by the ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) to refer to the device located at the end-user's premises. It is specifically a single-subscriber device.
- **ONU:** This is the term used by the IEEE (Institute of Electrical and Electronics Engineers) for a device that terminates a PON line. An ONU can be at the user's premises or it can be a multi-user device located in a curbside cabinet or building, serving multiple subscribers in a small area. The individual users are then connected to the ONU via another access network, which can be twisted-pair copper, coaxial cable, or even Wi-Fi.

In essence, while they are conceptually similar, an ONT is a type of ONU that is specifically deployed at the individual subscriber's location.

1.3.6 Network Maintenance Checklist

Proactive network maintenance is crucial for ensuring network stability, security, and performance. While new technologies may introduce new tasks, the fundamental principles of network upkeep remain constant. The following are key tasks that should be part of any network maintenance schedule.

1. Data Backups: Regular data backups are the most critical network maintenance task. They are essential for disaster recovery in case of hardware failure, cyberattacks, or other unforeseen events.

- **Frequency:** Backups should be scheduled based on the business's needs, ranging from continuous backups to daily or weekly backups.
- **Verification:** Regularly test and verify the integrity and readability of backed-up data. A backup is useless if it cannot be restored when needed.
- **Storage:** Store backups securely, both locally and in a remote or off-site location to protect against physical threats like fire or flood.

2. Malware and Security Protection:

With the increasing threat of cyberattacks, maintaining robust security is paramount.

- **Software Updates:** Keep all security software, server operating systems, and network device firmware up-to-date with the latest patches.
- **Monitoring:** Implement continuous monitoring to detect and respond to emerging threats.
- Testing: If possible, use a separate, isolated test network to try out major software updates before deploying them on the live network.

3. Documentation Updates:

Accurate and up-to-date network documentation is vital for quick and effective troubleshooting.

- Record Keeping: Log all network changes, repairs, and updates, including the date, time, the person who made the change, and the reason.
- Inventory: Maintain a current inventory of all network devices, including their names, locations, IP addresses, and MAC addresses.

4. Power System Checks:

Power failures can bring down an entire network

- **Redundancy:** Connect critical network equipment to multiple, independent power sources if possible.
- **UPS Testing:** Regularly test Uninterruptible Power Supply (UPS) systems to ensure they can provide a reliable power source during an outage.
- **Capacity Planning:** Ensure UPS capacity is sufficient for current and future network expansion.

5. Physical Maintenance:

Neglecting the physical environment can lead to equipment failure

- **Dust Filters:** Regularly inspect and clean or replace air filters on network equipment and cooling units. Clogged filters can lead to overheating, which reduces device performance and lifespan.
- **Cable Management:** Organize and secure all network cables to prevent accidental disconnection. Poor cable management is a common cause of network outages due to accidental trips or dislodged connections.

Notes

UNIT 1.4: Electromagnetic Spectrum (EMS)

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the key aspects and properties of the Electromagnetic Spectrum.
2. Describe the features of electromagnetic waves.
3. Identify the main regions of the Electromagnetic Spectrum and their applications.

1.4.1 The Electromagnetic Spectrum

The electromagnetic spectrum is the full range of all possible frequencies of electromagnetic radiation. An electromagnetic wave is a transverse wave that consists of mutually perpendicular oscillating electric and magnetic fields. These fields are also perpendicular to the direction of the wave's propagation.

The electromagnetic spectrum is a continuous range of waves, organized by increasing frequency (or decreasing wavelength). The major categories of electromagnetic radiation, from lowest to highest frequency, are:

- Radio waves
- Microwaves
- Infrared radiation
- Visible light
- Ultraviolet (UV) radiation
- X-rays
- Gamma rays

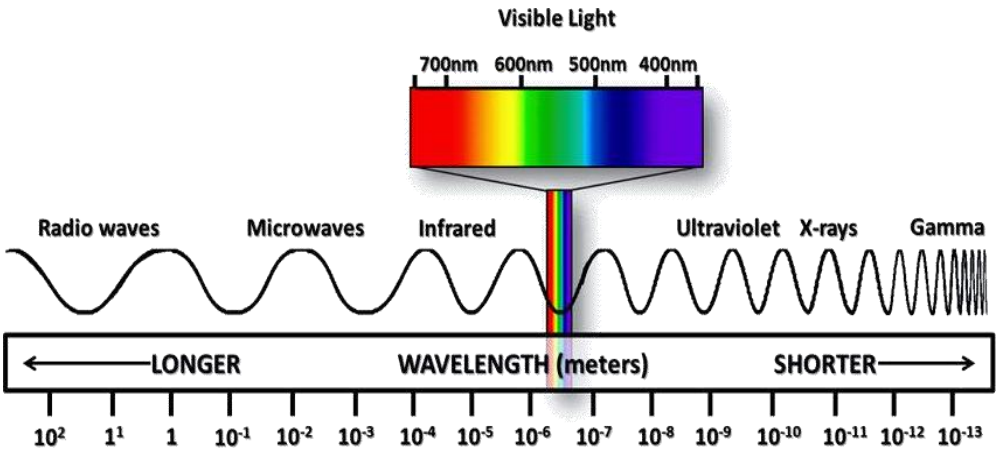

Fig. 1.4.1 Electro Magnetic Spectrum

It is important to note that these divisions are not distinct boundaries but rather a continuous "fusion" of one type of wave into the next.

1.4.2 Features of Electromagnetic Waves

Electromagnetic waves are a collective term for all forms of electromagnetic radiation. They share several key properties:

- **Speed:** All electromagnetic waves travel at the speed of light in a vacuum, which is approximately 3×108 meters per second (300,000,000 m/s or 186,000 miles per second). This fundamental property was first theorized by James Clerk Maxwell and later confirmed by Heinrich Hertz.
- **Wavelength and Frequency:** The different types of electromagnetic waves are distinguished by their wavelength (λ) and frequency (f). These two properties are inversely related by the equation c=fλ, where c is the speed of light. This means that waves with higher frequencies have shorter wavelengths, and waves with lower frequencies have longer wavelengths.
- **Energy:** The energy of a photon (the particle of light) is directly proportional to its frequency, as described by the equation E=hf, where h is Planck's constant. This means that high-frequency waves (like gamma rays) carry much more energy than low-frequency waves (like radio waves).

Historical Context:

- **Maxwell's Equations:** In the 1860s, James Clerk Maxwell developed a set of equations that unified electricity, magnetism, and optics, showing that light itself is an electromagnetic wave.
- **Hertz's Experiments:** In the late 1880s, Heinrich Hertz experimentally confirmed Maxwell's theory by generating and detecting radio waves, demonstrating that they exhibit the same wave properties as light. Hertz also observed the photoelectric effect, where UV light influenced the flow of electric current. These experiments laid the foundation for wireless communication.

1.4.3 Uses and Frequency Ranges of the Electromagnetic Spectrum

Each region of the electromagnetic spectrum has unique properties that make it suitable for specific applications.

Region of the Spectrum	Typical Wavelength Range	Typical Frequency Range	Key Applications
Radio Waves	104 m to 10−1 m	3 kHz to 3 GHz	Broadcasting (AM/FM radio, TV), wireless communication, radar, and satellite communication. Their long wavelength allows them to travel long distances and diffract around obstacles.

Microwaves	10−1 m to 10−3 m	3 GHz to 300 GHz	Cooking (absorbed by water molecules), satellite communication, GPS, and Wi-Fi. Microwaves can penetrate the Earth's atmosphere.
Infrared (IR)	10−3 m to 7×10−7 m	300 GHz to 430 THz	Heat detection (thermal imaging), remote controls, night vision equipment, and medical therapy. All objects with a temperature above absolute zero emit infrared radiation.
Visible Light	7×10−7 m to 4×10−7 m	430 THz to 750 THz	Human vision, photography, and optical fibers. This is the only part of the spectrum that is visible to the human eye. The colors of the visible spectrum range from red (longest wavelength) to violet (shortest wavelength).
Ultraviolet (UV)	4×10−7 m to 10−8 m	750 THz to 30 PHz	Fluorescent lamps (UV is converted to visible light), sterilization of medical equipment, and tanning beds. Can be harmful to living tissue in high doses.
X-Rays	10−8 m to 10−11 m	30 PHz to 30 EHz	Medical imaging (to see bones and internal structures), airport security scanners, and astronomical observation. They can penetrate soft tissues but are absorbed by denser materials like bone.
Gamma Rays	<10−11 m	>30 EHz	Sterilization of food and medical equipment, radiation therapy to treat cancer, and astronomical research. They are the most energetic form of electromagnetic radiation and can penetrate most materials.

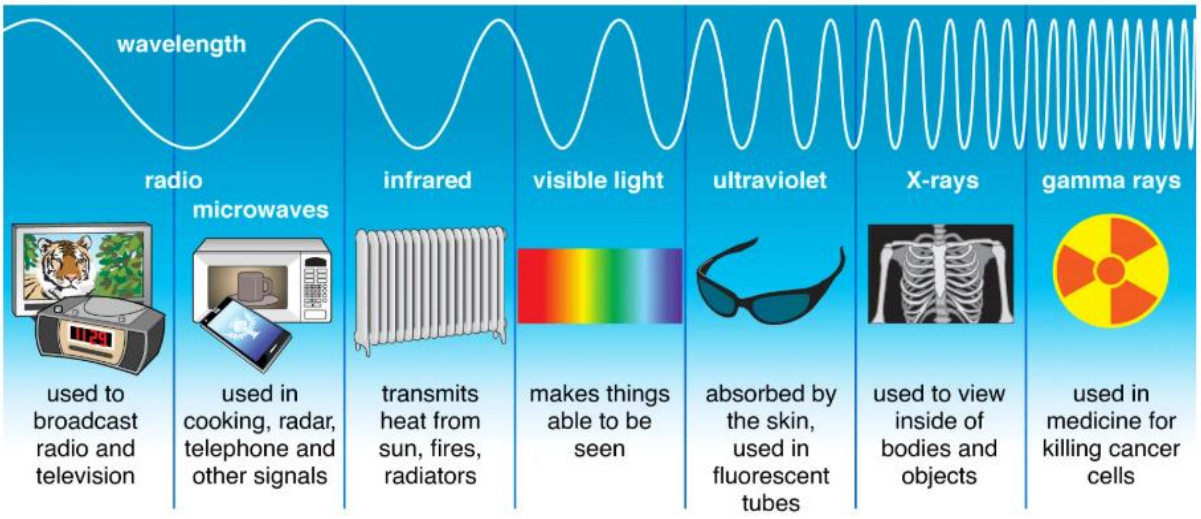

Fig 1.4.2 Uses of Electromagnetic Waves

Visible Light Spectrum:

The visible light portion of the spectrum is a very narrow band of frequencies. It is typically divided into colors based on wavelength:

- Red: ~620-750 nm
- Orange: ~590-620 nm
- Yellow: ~570-590 nm
- Green: ~495-570 nm
- Blue: ~450-495 nm
- Violet: ~400-450 nm

All forms of electromagnetic radiation (EMR) are a type of radiant energy. While visible light is the only part of the spectrum our eyes can detect, all other forms, from radio waves to gamma rays, are invisible to us.

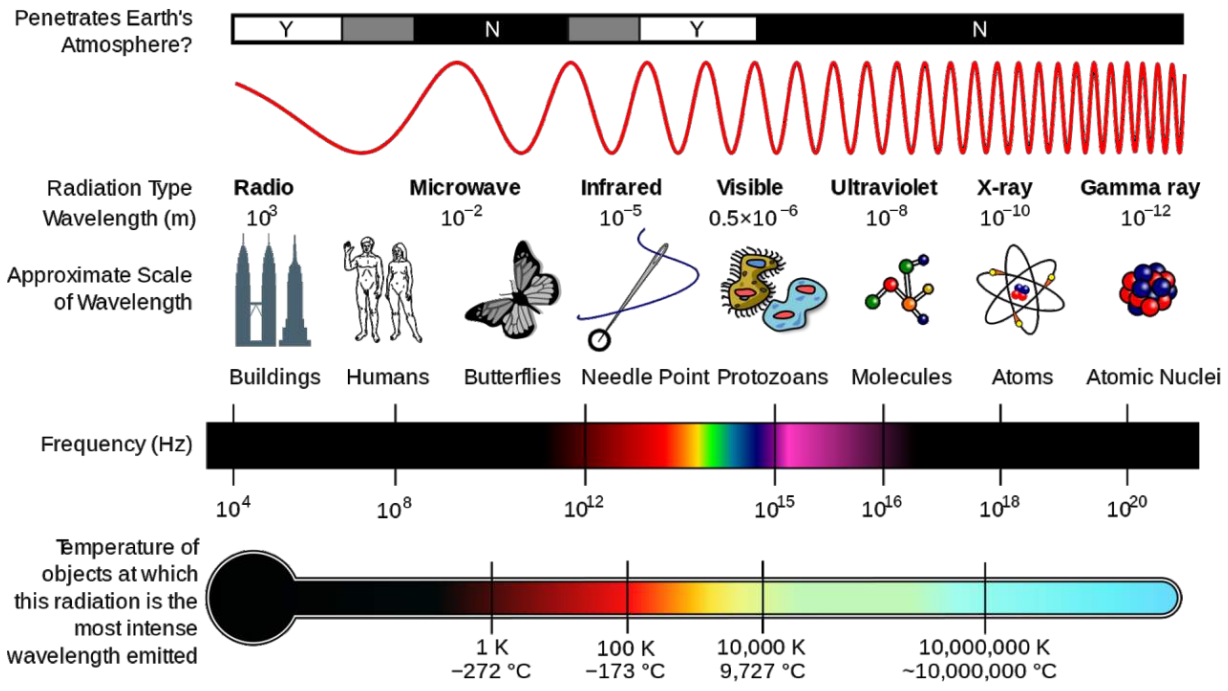

Fig 1.4.3 Electromagnetic Spectrum Light visible range

Notes

UNIT 1.5: Introduction to Mobile Technology

Unit Objectives

By the end of this unit, the participants will be able to:

1. Give an overview of the history and evolution of mobile technology.
2. Explain the key characteristics and technological advancements of each generation (1G, 2G, 3G, 4G, and 5G) of mobile communication.

1.5.1 Overview of Mobile Technology

The concept of mobile communication has evolved significantly since its inception. While the foundations were laid by inventors like Guglielmo Marconi with his wireless telegraph in 1895, the development of true mobile communication systems can be divided into distinct eras:

- Pioneer Era (Pre-1920): This period was marked by early experiments with wireless telegraphy and radio broadcasting.
- Pre-Cellular Era (1920-1979): This era saw the development of mobile radio systems, primarily used by emergency services, taxis, and maritime operations. The first commercial mobile telephone service was launched by Bell Labs in the USA in 1946. These systems used a single, powerful transmitter to cover a wide area, which limited the number of simultaneous users.
- Cellular Era (1979-Present): This era began with the introduction of the cellular concept, a revolutionary idea proposed by Bell Labs. This concept involved dividing a large geographical area into smaller "cells," each served by a low-power base station. This allowed for the reuse of frequencies in non-adjacent cells, significantly increasing network capacity and enabling a larger number of users.

The cellular era has progressed through several generations of technology, each offering major improvements in performance and capabilities.

1.5.2 Generations of Mobile Communication Technologies

Over the past three decades, the mobile telecommunications industry has undergone a rapid evolution, from the first analog systems to the current digital networks.

1. 1G (First Generation)

- Introduction: Early 1980s.
- Technology: Analog cellular technology.
- Key Services: Provided basic voice services.
- Limitations: Poor voice quality, low capacity, no data services, and no digital encryption, making them susceptible to eavesdropping. Examples include AMPS (Advanced Mobile Phone System).

2. 2G (Second Generation)

- Introduction: Early 1990s.
- Technology: Digital cellular technology.
- Key Services: Introduced digital encryption for calls, and enabled data services like SMS (Short Message Service) and MMS (Multimedia Messaging Service).
- Key Advantage: Significant improvement in call quality, security, and network capacity compared to 1G. The first 2G network was launched in 1991 in Finland on the GSM (Global System for Mobile Communications) standard. 2G systems also utilized multiple access technologies like TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple Access) to manage user traffic more efficiently.

3. 3G (Third Generation)

- Introduction: Early 2000s.
- Technology: Based on the IMT-2000 (International Mobile Telecommunications-2000) standards set by the International Telecommunication Union (ITU).
- Key Services: Enabled a true mobile broadband experience with significantly higher data rates. This supported new applications such as video calls, mobile internet access, and streaming services.
- Evolution (3.5G): Technologies like HSPA (High-Speed Packet Access), often referred to as 3.5G, were introduced to provide even better performance and faster data speeds, serving as a stepping stone to 4G.

4. 4G (Fourth Generation)

- Introduction: Late 2000s.
- Technology: All-IP (Internet Protocol) based networks.
- Key Services: Offered a substantial leap in data speeds, enabling high-definition mobile video streaming, online gaming, and other data-intensive applications. It is often synonymous with LTE (Long-Term Evolution) technology.
- Evolution (4.5G/LTE-Advanced): LTE-Advanced and similar technologies were developed to provide even faster speeds and greater network efficiency, meeting the growing demand for mobile data and preparing networks for the transition to 5G.

5. 5G (Fifth Generation)

- Introduction: Late 2010s.
- Technology: Designed to support a massive number of devices and a wide range of use cases beyond traditional mobile broadband.
- Key Services: Massive increase in data speeds (up to 10 Gbps), ultra-low latency, and support for a vast number of connected devices. 5G is the foundation for new technologies like the Internet of Things (IoT), autonomous vehicles, and smart cities. It is designed to be highly flexible and scalable to meet the diverse needs of future applications.

Notes

UNIT 1.6: Introduction to Optical Communication Systems

Unit Objectives

By the end of this unit, the participants will be able to:

1. Understand the fundamental need for fiber-optic communication.
2. Describe the key components and functions of an optical communication system.
3. Explain the role of optical fibers as a communication channel.
4. Identify the functions of optical transmitters and receivers.

1.6.1 Need for Fiber-Optic Communications

The modern era is defined by an explosive growth in data traffic, driven by applications such as streaming video, cloud computing, and the Internet of Things (IoT). This unprecedented demand for bandwidth has necessitated a shift from traditional copper-based communication systems to a more capable medium: optical fiber.

Optical fiber technology is a revolutionary invention in telecommunications for several reasons:

- High Bandwidth: Optical fibers can carry a massive amount of data, far exceeding the capacity of traditional copper cables. This is due to the extremely high carrier frequencies of light (around 200 THz), compared to the GHz range of microwave and radio systems.
- Long-Distance Transmission: Optical fibers enable data transmission over much greater distances with minimal signal loss and attenuation. The low loss of modern silica fibers (as low as 0.2 dB/km) allows signals to travel hundreds of kilometers without needing regeneration.
- Low Interference: Unlike electrical cables, optical fibers are immune to electromagnetic interference (EMI), which ensures signal integrity and reliability.
- Support for High Data Rates: Fiber-optic systems support incredibly high data rates, from the backbone network to the access network, making them the medium of choice for modern high-speed internet and telecom services.

1.6.2 Optical Communication System

An optical communication system transmits information using light as the carrier wave. At a fundamental level, it functions similarly to other communication systems, but it operates at optical frequencies.

A generic optical communication system consists of three main parts:

- Transmitter: Converts the electrical signal into an optical signal.
- Communication Channel: The medium through which the optical signal travels (e.g., optical fiber).
- Receiver: Converts the optical signal back into an electrical signal.

A diagram showing the basic components of an optical communication system.

Optical fiber communication systems have been developed primarily for telecommunication applications, categorized by distance: long-haul and short-haul. Long-haul applications, such as high-capacity trunk lines, have been the main drivers of innovation in optical fiber technology due to their need for minimal loss over great distances.

1.6.3 Optical Fibers as a Communication Channel

The optical fiber is the medium that guides the light signal from the transmitter to the receiver. It is a hair-thin strand of high-purity glass (silica) or plastic.

Signal Regeneration in Early Systems

Early long-distance fiber optic systems relied on electronic repeaters to compensate for signal loss and degradation. These repeaters were installed at intervals of approximately 40-60 km.

- Process: The repeater station would receive the optical signal, convert it back into an electrical signal, regenerate it (reshape and re-time it), and then use a new optical transmitter to send the signal down the next segment of fiber.
- Limitation: Repeaters were speed-sensitive and costly, requiring all devices in the link to be replaced to upgrade the data rate.

Key Fiber Characteristics and Impairments

For a communication channel to be effective, it must transmit the signal with minimal degradation. Two primary characteristics of optical fiber impact system design:

- Attenuation (Loss): This is the reduction in optical power as the light signal travels through the fiber. For silica glass, the average loss is very low (around 0.2 dB/km), meaning a signal loses only about 1% of its power over 100 km. However, this loss must still be accounted for to determine the required spacing for amplifiers or repeaters.
- Dispersion: This refers to the spreading of the light pulses as they travel down the fiber. Dispersion causes the pulses to broaden, which can lead to overlapping and make it difficult for the receiver to distinguish between individual bits, leading to a loss of data.
    - Modal Dispersion: Occurs in multimode fibers where different light rays (or modes) travel at different speeds, causing significant pulse spreading. This is why multimode fibers are generally used for short-distance applications.
    - Chromatic Dispersion: Occurs in single-mode fibers due to the different speeds of light at different wavelengths. Even with a single-mode fiber, a light source emits a narrow range of wavelengths, and this can cause pulse broadening. This is a key factor in long-haul systems.

Wavelength Division Multiplexing (WDM)

Modern long-haul optical systems overcome bandwidth limitations by using Wavelength Division Multiplexing (WDM). This technology allows multiple, independent optical channels to be transmitted simultaneously over a single fiber by using a different wavelength (or color) for each channel. This effectively multiplies the capacity of a single fiber, supporting massive data rates.

1.6.4 Optical Transmitters and Receivers

1. Optical Transmitter

The optical transmitter is the first component in the system chain. Its function is to convert the electrical signal from a data source into an optical signal and launch it into the fiber.

A typical optical transmitter comprises:

- Light Source: Generates the optical signal. Common sources are Laser Diodes (LDs) or Light Emitting Diodes (LEDs). Lasers are preferred for long-haul, high-speed applications due to their high power and narrow spectral width.
- Modulator/Driver: Controls the light source to encode the electrical data onto the optical signal (e.g., by rapidly turning the light on and off for digital data).
- Coupler/Connector: Couples the light from the source into the core of the optical fiber with minimal loss.

2. Optical Receiver

The optical receiver is the final component in the system. Its role is to detect the incoming optical signal and convert it back into the original electrical signal for processing by the destination device.

A typical optical receiver consists of:

- Coupler/Connector: Focuses the incoming light signal onto the photodetector.
- Photodetector: The key component that converts light photons into an electrical current. Common types include PIN photodiodes and Avalanche Photodiodes (APDs).
- Demodulator/Amplifier: Amplifies the weak electrical signal from the photodetector and processes it to recover the original data.

Exercise

Short Questions:

1. List three-character traits that make an ONT Technician effective.
2. What is the role of patch cords and pigtails in ONT operations?
3. Differentiate between ONT and ONU.
4. Mention two occupational risks faced by ONT Technicians.
5. Why is cable management important in network maintenance?

Multiple Choice Questions:

1. The main function of an Optical Network Terminal (ONT) is to:
   a) Convert electrical signals into radio signals
   b) Convert optical signals into electrical signals
   c) Store customer data locally
   d) Act as a power backup system
2. Which of the following is not a key competency of an ONT Technician?
   a) Operation of CCU, SPV, TJB
   b) Understanding of optical patch cords
   c) Managing a large team of employees
   d) Proficiency in diagnostic devices
3. The ONT is usually installed at:
   a) The telecom operator's headquarters
   b) The user's premises at the termination point
   c) Inside the mobile base station
   d) A satellite ground station
4. Which of the following is a health and safety risk for an ONT Technician?
   a) Electric shocks
   b) Data loss
   c) Network congestion
   d) Slow internet speed
5. According to ITU-T standards, a device located at the end-user premises is called:
   a) ONU
   b) ONT
   c) OLT
   d) Router

Fill in the Blanks:

1. An ONT converts _____ signals into _____ signals used by a router.
2. ONT Technicians ensure the _____ functionality of ONT sites through maintenance and repairs.
3. The ITU-T uses the term ONT, while the IEEE uses the term _____.
4. One key career progression option for an ONT Technician is becoming a _____ Service Engineer.
5. Regular _____ are considered the most critical network maintenance task for disaster recovery.

Notes

2. Maintaining Site Hygiene and Implement Security

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Key Learning Outcomes

By the end of this module, the paricipants will be able to:

1. Explain the fundamentals of computer networks, including their purpose, components, and evolution.
2. Differentiate between various types of networks such as LAN, WAN, MAN, and PAN, based on scale, functionality, and use cases.
3. Analyze common network topologies (e.g., star, bus, ring, mesh) and evaluate their advantages and limitations.
4. Interpret and assign IP addresses, understanding IPv4 and IPv6 formats and their roles in network identification.
5. Explain how to apply subnetting techniques to divide networks efficiently and enhance routing and security.
6. Elaborate on how to configure basic network connectivity settings, including IP configuration, gateway setup, and DNS resolution, to establish reliable communication between devices.

UNIT 2.1: Overview of Computer Networks

Unit Objectives

By the end of this unit, the participants will be able to:

1. Understand the fundamental concepts of computer networks.
2. Differentiate between various types of networks (LAN, MAN, WAN).
3. Categorize networks based on their architectural models (Peer-to-Peer, Client-Server).
4. Recognize and explain the different types of network topologies.

2.1.1 Overview of Computer Networks

A computer network is an interconnection of a group of computers and other devices that are linked together to enable communication and resource sharing. These resources can include hardware like printers and hard disks, or software and data. The initial idea for a network was conceived by the Department of Defense (DoD) in the USA to ensure secure and resilient communication.

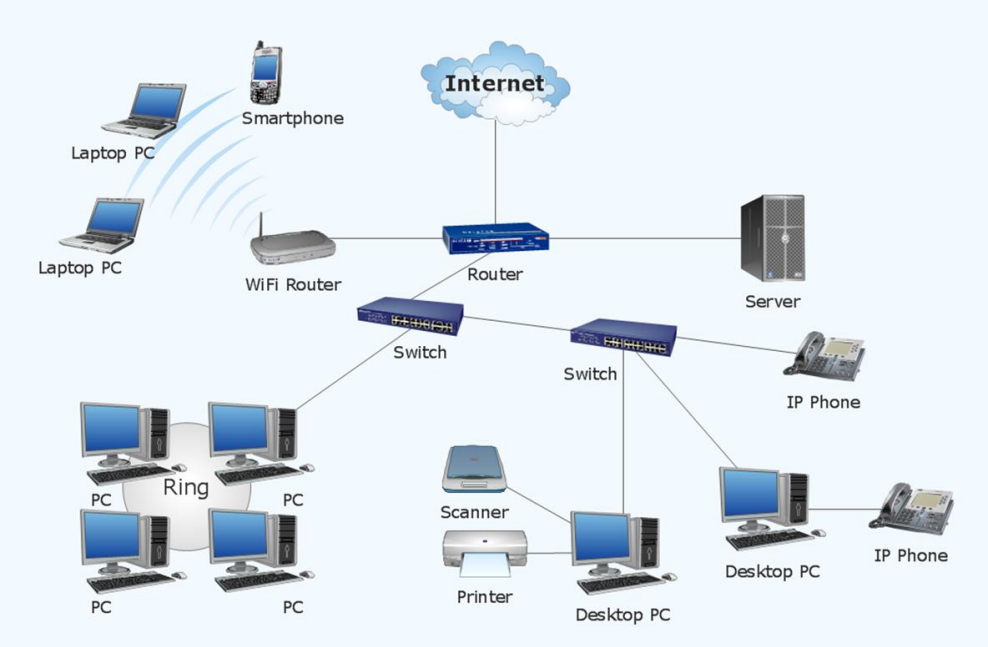

Fig 2.1.1 Computer Network

Advantages of Networks:

- Resource Sharing: Enables multiple users to share hardware (e.g., printers, scanners) and software, leading to cost savings.
- Information Sharing: Facilitates the easy and rapid exchange of information and data among users.
- Centralized Data Management: Allows data to be stored and managed centrally on a server, improving security, consistency, and ease of backup.
- Enhanced Communication: Provides platforms for communication tools such as email, instant messaging, and video conferencing.

2.1.2 Types of Networks

Networks are typically classified based on their geographical size and scale.

1. Local Area Networks (LANs)

- Description: A LAN is a network that covers a small, limited geographical area, such as a home, office building, or a school campus.
- Characteristics: High data transfer rates, low latency, and private ownership.

2. Metropolitan Area Networks (MANs)

- Description: A MAN is larger than a LAN but smaller than a WAN. It connects computers and resources within a metropolitan area, like a city or a large campus.
- Characteristics: A MAN often connects several LANs together and is typically managed by a single organization or a service provider.

3. Wide Area Networks (WANs)

- Description: A WAN provides network connectivity over a very large geographical area, spanning cities, countries, or even continents. The internet is the largest example of a WAN.
- Characteristics: Lower data transfer rates and higher latency compared to LANs. WANs are typically composed of multiple interconnected LANs.

Network Categories (Architectural Models)

Networks can also be categorized by their architectural model, which defines how devices interact with each other.

1. Peer-to-Peer (P2P)

- Description: In a P2P network, all computers are considered "peers," meaning they have equal status. Each device can function as both a client and a server, and can directly communicate with any other device on the network.
- Advantages: Easy to set up, low cost for small networks.
- Disadvantages: Difficult to manage as the network grows, lacks a centralized location for security and data backup.

2. Client-Server

- Description: This model is based on a hierarchical structure where centralized, powerful computers called servers provide resources and services to other devices called clients. The server manages data, security, and access to shared resources.
- Advantages: Centralized management, improved security, easier data backup and recovery, and better scalability.
- Disadvantages: Higher cost for setting up the server, and the entire network can be affected if the server fails.

2.1.3 Network Topology

Network topology refers to the physical or logical arrangement of the nodes and connections in a network.

1. Bus Topology

- Description: All devices are connected to a single, central high-capacity cable called the "bus" or "backbone." Data packets are broadcast down the bus, and only the intended recipient accepts the data.
- Advantages: Requires less cabling than other topologies, easy to set up for small networks.
- Disadvantages: A break in the main cable can disrupt the entire network. Performance degrades as more devices are added.

2. Star Topology

- Description: All nodes are connected to a central device, such as a hub or switch. All communication between nodes must pass through this central point.
- Advantages: Easy to add or remove nodes without disrupting the network. A single cable failure only affects one node.
- Disadvantages: The central hub is a single point of failure; if it fails, the entire network goes down. Requires more cabling than a bus topology.

3. Ring Topology

- Description: Each node is connected to exactly two other nodes, forming a single continuous loop or "ring." Data travels around the ring in one direction.
- Advantages: Simple to manage. Less susceptible to collisions than bus topology.
- Disadvantages: A single node or cable failure can break the entire ring. Adding a new node requires breaking the ring and reconfiguring the network.

4. Mesh Topology

- Description: Every node in the network is interconnected with every other node, creating multiple paths for data transmission.
- Advantages: Highly reliable and fault-tolerant due to multiple redundant paths. If one path fails, data can be rerouted.
- Disadvantages: Very expensive and complex to install and manage due to the extensive cabling required. Scalability is difficult as the number of connections grows exponentially with the number of nodes.

5. Cellular Topology (Wireless)

- Description: This is a wireless topology used in mobile phone networks. A large geographical area is divided into smaller "cells." Each cell is served by a central base station (cell tower) that provides a wireless connection to devices within its range.
- Advantages: High mobility for users. No need for physical cabling for end-user devices. Easy to add new cells to expand network coverage.
- Disadvantages: Signal strength and quality can vary. Performance can be affected by physical obstructions and interference.

Notes

UNIT 2.2: IP Addressing and Subnetting

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the structure and classes of IPv4 addressing.
2. Explain the concept and purpose of subnetting.
3. Demonstrate the practical steps for crimping an Ethernet cable.

2.2.1 IP Addressing

An Internet Protocol (IP) address is a unique numerical label assigned to each device connected to a computer network that uses the Internet Protocol for communication. Its primary purpose is to identify a host and its location on the network, enabling data to be routed correctly.

IPv4 Addressing:

- Structure: An IPv4 address is a 32-bit number, typically represented in dotted-decimal notation (e.g., 192.168.1.1). It is divided into four 8-bit sections called octets. Each octet can have a value from 0 to 255.
- Total Addresses: There are 232, or 4,294,967,296 possible IPv4 addresses. However, due to the rapid growth of the internet, this pool is nearly exhausted. The successor, IPv6, uses a 128-bit address space to solve this problem.
- Components: Every IP address is logically divided into two parts:
  - Network Address: Identifies the specific network the device is on.
  - Host Address: Identifies the specific device within that network.

Classes of IPv4 Addresses:

IPv4 addresses were originally divided into five classes to simplify administration and routing.

Class	First Octet Range	First Few Bits	Network & Host Bits	Purpose
Class A	1 - 126	0...	8 bits Network, 24 bits Host	For very large networks.
Class B	128 - 191	10...	16 bits Network, 16 bits Host	For medium to large networks.
Class C	192 - 223	110...	24 bits Network, 8 bits Host	For small to medium networks.
Class D	224 - 239	1110...	N/A	Reserved for Multicast.
Class E	240 - 255	1111...	N/A	Reserved for experimental use.

Note: The address 127.x.x.x (127 in the first octet) is reserved for the loopback address (127.0.0.1), used for testing and local communication on a single machine. The address 0.0.0.0 is the default route address.

Public vs. Private IP Addresses

To conserve the limited IPv4 address space, certain address blocks were designated as private IP addresses. These addresses are not routable on the public internet and can be used by anyone within their own private network (e.g., a home or office LAN).

Class	Private IP Address Ranges
Class A	10.0.0.0 to 10.255.255.255
Class B	172.16.0.0 to 172.31.255.255
Class C	192.168.0.0 to 192.168.255.255

Devices with private IP addresses use a technology called Network Address Translation (NAT) to communicate with the internet. A NAT router translates the private IP addresses to a single public IP address, allowing multiple devices on a private network to share one public IP.

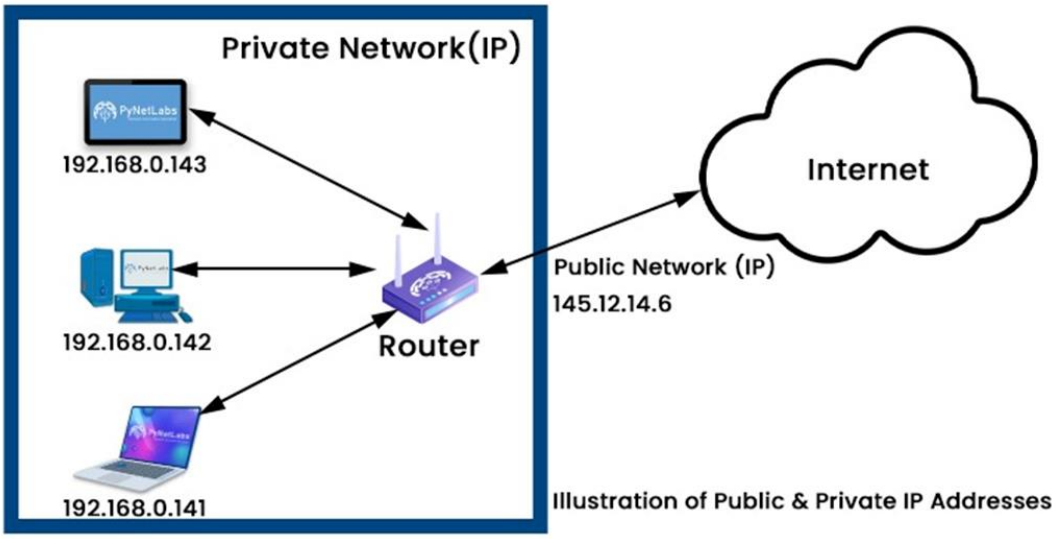

Fig 2.2.1 IP Addressing

Classless Inter-Domain Routing (CIDR)

CIDR is a modern addressing scheme that replaced the rigid class-based system. It allows for more efficient allocation of IP addresses by removing the boundaries of Class A, B, and C.

- CIDR Notation: An IP address with a CIDR suffix (e.g., 192.168.1.0/24) indicates the number of bits used for the network portion. /24 means the first 24 bits are the network address, and the remaining 8 bits are for the host address.
- Subnet Mask: The subnet mask is a 32-bit number used to logically separate the network and host portions of an IP address. In binary, the network bits are set to 1s and the host bits are set to 0s. For /24, the mask is 11111111.11111111.11111111.00000000, or 255.255.255.0 in decimal.

2.2.2 Subnetting

Subnetting is the process of dividing a single large network into smaller, more manageable sub-networks or "subnets."

Purpose and Benefits of Subnetting:

- Reduces Network Traffic: It segments broadcast traffic, ensuring that broadcast packets only reach hosts within their specific subnet, thereby reducing network congestion.
- Optimizes Performance: By localizing traffic, it improves network speed and efficiency.
- Enhances Security: Subnetting can be used to isolate sensitive parts of a network, preventing unauthorized access.
- Simplifies Management: It makes it easier to troubleshoot issues and manage a network by dividing it into smaller, logical units.

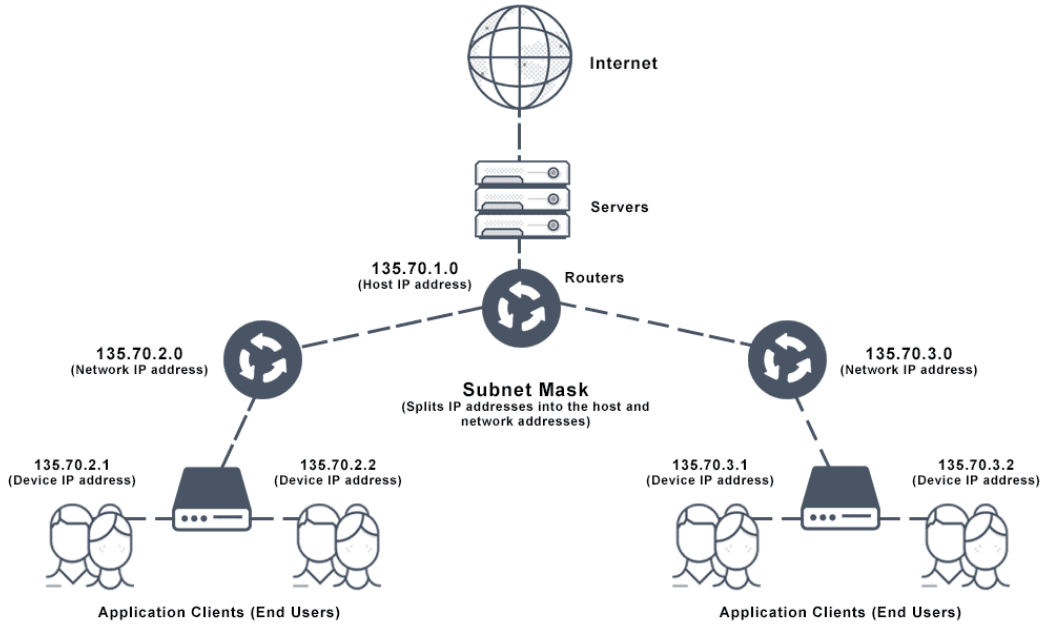

Fig 2.2.2 Subnetting

Key Principles of Subnetting:

- Subnetting is achieved by "borrowing" bits from the host portion of an IP address to create new network addresses.
- When subnetting, two host addresses within any subnet are always reserved:
  - The network address (all host bits are 0s).
  - The broadcast address (all host bits are 1s).
- The number of usable hosts is calculated using the formula 2^n-2, where n is the number of bits in the host portion.

2.2.3 Crimping an Ethernet Cable

Crimping an Ethernet cable is the process of attaching an RJ-45 connector to the end of an un-terminated twisted-pair cable. This is a crucial skill for network technicians.

Tools Required:

- Ethernet Cable
- RJ-45 Connectors
- Cable Stripper or Crimping Tool with Stripper
- Crimping Tool

Steps for Crimping (T568B Standard):

- Strip the Jacket: Use the stripper on the crimping tool to carefully cut and remove about one inch of the outer cable jacket. Be careful not to nick the inner wires.
- Untwist the Pairs: Gently untwist the four pairs of colored wires inside the cable jacket. Straighten each of the eight individual wires.
- Arrange the Wires: Arrange the wires in the correct sequence for either a straight-through or crossover cable. For a straight-through cable using the common T568B standard, the order is:
  - White/Orange, Orange
  - White/Green, Blue
  - White/Blue, Green
  - White/Brown, Brown
- Trim and Insert: Once the wires are in the correct order, trim the ends straight with a cutter to ensure they are all the same length. Insert the aligned wires into the RJ-45 plug, making sure each wire slides into its designated channel. Push the cable firmly into the plug until the wire ends touch the front of the connector and the cable jacket is inside the back of the plug.
- Crimp the Connector: Place the RJ-45 plug, with the cable inserted, into the designated slot on the crimping tool. Squeeze the crimper handles firmly until the tool ratchets back to its open position. This action presses the small metal pins (tines) down into each wire, creating a secure electrical connection.
- Repeat and Test: Repeat the process for the other end of the cable. For a straight-through cable, both ends must be crimped using the same wiring standard (e.g., T568B on both sides). For a crossover cable, one end is crimped with T568B and the other with T568A. Finally, use a cable tester to verify that all eight connections are working correctly.

Fig 2.2.3 Steps for Crimping

Note: Modern networking equipment often has an Auto-MDIX (Automatic Medium-Dependent Interface Crossover) feature, which automatically detects the cable type and configures the connection, making the use of crossover cables less common.

Notes

UNIT 2.3: Configuring Network

Unit Objectives

By the end of this unit, the participants will be able to:

1. Demonstrate the process of configuring network connectivity.

2.3.1 Configuring Network Connectivity

The networking functionality built into Windows 7 enables you to share all kind of resources with computer users. Before we can share the resources, the first thing we have to do is configure the network, what are the Hardware requirement, how to connect to the network and share the resources.

1. Hardware Requirements
2. Installing the Hardware
3. Connecting to the Network
4. Network & Sharing Center
5. Troubleshooting Networks

- Hardware Requirements: Most computers that exist in a family environment are used to share stuff, such as pictures, music, emails, etc., between members of the family. However, sharing data doesn't have to be so restricted; it can actually be shared with any computer, anywhere in the world.
- Networks come in two types: Wired, which uses network cables and Wireless, which uses wireless radio signals. For the home user, the latter is the best option and is the one we describe here. To get going, you will need:
- Wireless Adapter: This is a component that enables a computer to send and receive signals wirelessly. Many computers have this functionality built-in, but not all do. To find out if yours does, open the Settings app from the Start menu and go to Network & the Internet. If you see a Wi-Fi option at the top of the window, you're ready to go. If you don't see a WiFi option, you need to go out and buy a wireless adapter from your local computer store. These cost a few dollars and simply plug into a USB port on the PC.
- A Wireless Router: Also known as a network controller, a router is a device that connects your computer to the Internet – wireless versions do it without the need for cabling. Many homes these days have a wireless router already installed as part of their broadband setup. If you don't have one, though, as with the adapter, you'll need to acquire one and install it. The router will come with an installation disc that lets you set up the device and configure various security settings.

Definition of the router:

Process of routing is forwarding IP packet or IP datagram from starting/initiated node to reaching node which located in another remote network. This process is carried out by special devices called Routers. Routers can process and identify special address called IP address and which will examine and verify destination IP address and next hope IP addresses. A router forwards this packet to next hop address and which will continue this operation until it reaches destination node. Routers are utilizing routing tables to determine next hope address.

Connecting to the Network: Once you installed and configured the hardware, we need to set up the Network.

The steps followed are as follows:

- Open the Settings app and click Network & The Internet
- If all has gone to plan, you will see a Wi-Fi entry as shown below. This indicates the wireless network is up-and-running
- Select the Wi-Fi entry to open the connection window: As seen in the Fig.2.2.7
- Click the Connect button to connect your computer to the network. When it is, the network will show as Connected

Notes

UNIT 2.4: Optical Line Terminal (OLT) and Network Operations Center (NOC)

Unit Objectives

By the end of this unit, the participants will be able to:

1. Differentiate between the functions and components of an Optical Line Terminal (OLT) and a Network Operations Center (NOC).
2. Explain the roles of a Network Operations Center (NOC) and a Security Operations Center (SOC) and their collaborative relationship.
3. Describe the significance of the BharatNet project and the communication protocols for Field Engineers when interacting with local officials.

2.4.1 Optical Line Terminal (OLT)

An Optical Line Terminal (OLT) is a critical piece of hardware in a Passive Optical Network (PON). Located at the service provider's central office, it serves as the central control point and the starting point for the fiber-optic network.

Key Functions of an OLT:

- Ethernet to PON Conversion: It receives Ethernet data from the provider's core network and converts it into optical signals for transmission over the PON.
- Bandwidth Allocation: The OLT uses protocols like Time Division Multiple Access (TDMA) to manage and allocate bandwidth to each Optical Network Unit (ONU) or Optical Network Terminal (ONT) in the network. This ensures fair and efficient use of the shared fiber.
- Ranging and Management: The OLT initiates a "ranging" operation to determine the distance to each ONU/ONT and adjusts their transmission timing. This prevents data packets from multiple users from colliding on the shared upstream channel.
- Data Flow Management: It manages data traffic in two directions:
    - Downstream: Sends data (voice, video, and internet traffic) from the metropolitan or long-haul network to all connected ONT modules.
    - Upstream: Receives, aggregates, and distributes data and voice traffic from individual users.
- Distance: The OLT can support data transmission over distances up to 20 km across the Optical Distribution Network (ODN).

Standard Components of an OLT:

An OLT unit is typically housed in a rack and comprises several modules for its operation, including:

- Chassis: The main frame for holding all components.
- Control and Switch Module (CSM): Manages the entire OLT and switches data traffic.
- PON Card (EPON/GPON Link Module): The heart of the OLT, containing the optical ports that connect to the fiber distribution network. These cards are often hot-swappable, allowing for easy replacement without shutting down the system.
- Power Supply Modules: Provide power to the OLT. These can be -48V DC or 110/220V AC modules, often with redundancy for reliability.
- Fans: Provide cooling to prevent overheating.

2.4.2 Network Operations Center (NOC)

A Network Operations Center (NOC) is a centralized location where IT teams monitor and manage the performance, health, and availability of an organization's computer networks. The NOC acts as the first line of defense against network failures and disruptions.

Key Responsibilities of a NOC:

- Proactive Monitoring: The NOC provides comprehensive visibility into network performance, allowing technicians to identify anomalies and potential issues before they cause service disruptions.
- Incident Management: When an issue is detected, the NOC is responsible for:
  - Issue Triage: Prioritizing network problems based on severity.
  - Troubleshooting: Working to resolve issues within their designated area of expertise.
  - Incident Tracking: Using a ticketing system to thoroughly document all issues and their resolutions.
  - Escalation: Escalating complex problems to higher-level IT teams, management, or third-party vendors.
- Customer Experience: NOC services often include monitoring customer support calls and integrating with help desk systems to ensure a positive customer experience by rapidly addressing service-affecting issues.
- Device Management: A NOC manages a wide range of network-related devices, including routers, switches, servers, firewalls, and more recently, IoT devices and wireless systems.

NOC vs. SOC (Security Operations Center)

While both the NOC and Security Operations Center (SOC) perform critical monitoring and incident response functions, their focuses are distinct.

Feature	Network Operations Center (NOC)	Security Operations Center (SOC)
Primary Goal	Performance & Availability. To ensure the network is running smoothly and is always available.	Security & Protection. To protect the organization from cyber threats and data breaches.
Focus	Network performance, traffic flow, system uptime, and hardware health.	Cybersecurity threats, vulnerabilities, malware, and unauthorized access attempts.
Threats Handled	Internal, naturally occurring network events, such as hardware failures, link outages, or traffic congestion.	External, malicious threats, such as hacking attempts, DDoS attacks, and data exfiltration.
Key Skills	Network and application monitoring, troubleshooting, and infrastructure management.	Threat detection, incident response, forensic analysis, and knowledge of cybersecurity tools.

Both teams work to identify, investigate, and resolve problems quickly. Their distinct focuses mean that NOC and SOC technicians possess different skill sets and expertise, making both essential for a company's overall operational health.

2.4.3 Coordination with Gram Panchayat Officials

The Gram Panchayat is the fundamental institution of rural self-governance in India, serving as the grassroots democratic body in a village or group of villages.

The BharatNet project, formerly known as the National Optical Fibre Network (NOFN), is a flagship initiative by the Government of India to digitally connect all Gram Panchayats and villages. It aims to provide high-speed broadband connectivity to over 250,000 village panchayats across the country.

- Executing Body: The project is implemented by the Department of Telecommunications under the Ministry of Communications, with Bharat Broadband Network Ltd. (BBNL) serving as a Special Purpose Vehicle (SPV) to manage its execution.
- Purpose: BharatNet establishes a middle-mile network from blocks to panchayats, which can be leveraged by Internet Service Providers (ISPs), local cable operators, and other organizations to provide last-mile connectivity and digital services to rural citizens. This enables access to essential e-governance, telemedicine, and e-education services.

Field Engineers involved in the deployment and maintenance of the BharatNet project must coordinate effectively with Gram Panchayat (GP) officials. Their key responsibilities in this context include:

- Pre-Deployment Communication: Informing GP officials about site visits, work schedules, and project goals to ensure smooth access and local cooperation.
- System Monitoring: Using various techniques to monitor the functionality and performance of deployed network systems.
- Troubleshooting: Working to prioritize and resolve network issues within their designated areas.
- Incident Tracking: Thoroughly documenting all faults and fixes in a specific ticketing system for project tracking and reporting.
- Incident Reporting: Escalating complex problems to management, other technical teams, or vendors as necessary.
- Reporting and Documentation: Documenting site visits and audits, and reporting findings to the deployment team on a regular basis.
- Quality Assurance: Discussing action plans with third-party providers to enhance workmanship and ensure the quality of installations.
- Third-Party Coordination: Aiding and coordinating with third-party field teams to resolve on-site issues.

Notes

UNIT 2.5: Equipment Used at the Site)

Unit Objectives

By the end of this unit, the participants will be able to:

1. Describe the various types of equipment commonly used at a telecommunication site.
2. Discuss the best practices for wiring setup, maintenance, and repair to ensure site efficiency and safety.

2.5.1 Charge Controller Unit (CCU)

A Charge Controller Unit (CCU) is an essential component of an off-grid solar power system. Its primary function is to regulate the voltage and current flowing from the solar panels to the battery bank, preventing the batteries from being overcharged.

- Function: Solar panels (typically 12V) can produce a voltage in the range of 16V to 20V, which is too high for safe battery charging. A charge controller steps down this voltage to the optimal level for batteries (typically 14V to 14.5V for a full charge), directing any excess power to the connected loads.
- Types: Charge controllers vary in size and features. The three main types are:
    - Simple On/Off Controls: Basic controllers that simply stop charging when the battery reaches a certain voltage.
    - PWM (Pulse Width Modulation): A more advanced type that regulates the charging process by sending a series of short charging pulses to the battery.
    - MPPT (Maximum Power Point Tracking): The most efficient type of controller. It continuously tracks the optimal voltage and current from the solar panels to maximize the power transferred to the batteries, especially in varying light conditions.

2.5.2 Solar Photo Voltaic System (SPV)

A Solar Photo Voltaic (SPV) system is a technology that converts sunlight directly into direct current (DC) electricity using solar cells. The electricity generated can be used immediately or stored in batteries for later use, such as at night.

Salient Features of SPV Systems:

- Environmental Benefits: They are pollution-free, quiet in operation, and do not rely on fossil fuels.
- Ease of Use: SPV systems are relatively easy to install and operate, making them suitable for remote sites.
- Longevity: SPV panels have a long lifespan, typically lasting for several decades with minimal degradation.
- Low Maintenance: The systems require very little maintenance once installed.

2.5.3 Telephone Junction Box (TJB)

A Telephone Junction Box (TJB) is a type of terminal box used in telecommunication networks. Its function is to manage and organize the wiring for a small number of telephone lines.

- Purpose: In a telecom network, multiplexed lines (such as T1 or T3 lines) carry numerous voice channels. A TJB is used to separate these multiplexed lines into individual twisted-pair connections that can be routed to each home or telephone.
- Application: While simple terminal boxes are used for specific connections with no planned expansion, a junction box is designed with more usable space, allowing for future growth and the addition of new connections as needed.

2.5.4 Battery Bank

A battery bank is an assembly of one or more individual batteries configured together to store electrical energy in a chemical form. They are used to provide backup power during outages or to supply energy to equipment when the primary power source (e.g., solar panels) is not active.

2.5.5 Fire Extinguisher

Fire safety is a critical concern at sites with sensitive and costly IT and telecom equipment. Although the risk of a fire starting in the equipment itself is low due to limited combustible material, external factors or electrical faults can still pose a risk.

- Fire Detection: Automatic smoke-detection systems are essential for providing an early warning of a fire. These systems should be linked to an alarm that annunciates in a location that is constantly monitored.
- Extinguisher Type: An ABC extinguisher is the most common and versatile type for these environments. It is a multi-purpose dry chemical extinguisher that is effective on fires involving:
  - A: Combustible solids (e.g., wood, paper).
  - B: Flammable liquids (e.g., grease, oil).
  - C: Electrical equipment.

Note: While dry chemical extinguishers are effective, they can leave a residue that may damage sensitive electronics. For data centers and server rooms, other types like CO2 or clean-agent (e.g., FM-200) extinguishers are often preferred as they do not leave a residue.

2.5.6 Wiring Setup, Maintenance, and Repair

The functionality and reliability of any site depend heavily on the proper installation and maintenance of its cables and wires. Adhering to best practices can prevent downtime and costly repairs.

Preventive Measures Before Installation:

- Inspect Cables: Always check cables for any physical damage or scratches that could compromise their integrity.
- Mind the Bend Radius: Never bend cables beyond their specified bend radius to avoid internal damage.
- Avoid Tension and Kinking: Ensure that wires are not under tension and are not twisted or kinked during installation.
- Prevent Contact with Hazards: Keep cables away from sources of heat, sharp objects, or anything that could cause physical damage.

Maintenance Advice:

- Right Cable for the Job: Select the appropriate wire or cable type and size for the specific application, considering factors like mechanical strength, operating temperature, and voltage requirements.
- Staff Training: Regularly train staff to identify signs of potential wire or cable failure, such as overheating, frayed jackets, or physical damage.
- **Damage Prevention:**
  - Monitor the installation process to ensure wires are laid straight and without twists.
  - Prevent crushing, piercing, or other forms of physical trauma to the cables.
  - Keep cables away from open flames and sources of excessive heat.
- Cable Reel Adjustments: If using cables from a reel, adjust them regularly to prevent one end from being exposed to the environment for an extended period. Maintain the appropriate tension and note the overload current rating.
- **Timely Repairs:**
  - Conduct regular inspections to identify damaged wires or cables.
  - Promptly repair or replace any damaged sections. A crushed or compromised cable should be removed before it leads to a catastrophic failure.
- **Maintain Records:**
  - Keep a detailed inventory of all installed cables and wires, including their type, length, and installation date.
  - Document the cable layout and a record of common fault locations for future reference.
  - Record all repairs and performance analyses to track the lifespan and reliability of the cables.

Exercise

Short Questions:

1. List two advantages of using a computer network.
2. Differentiate between LAN and WAN.
3. State the main difference between a NOC and a SOC.
4. Why are fire extinguishers critical at telecom sites, and which type is most commonly used?
5. Write two preventive measures to be taken before cable installation at a telecom site.

Multiple Choice Questions:

1. Which of the following is the largest type of computer network?
   a) LAN
   b) MAN
   c) WAN
   d) PAN
2. In a star topology, all devices are connected to:
   a) A backbone cable
   b) A central hub or switch
   c) Two adjacent devices in a loop
   d) Multiple paths with every device
3. Which IP address class is designed for very large networks?
   a) Class A
   b) Class B
   c) Class C
   d) Class D
4. The device located at the service provider's central office that converts Ethernet signals into optical signals is called:
   a) ONU
   b) ONT
   c) OLT
   d) Router
5. The BharatNet Project aims to:
   a) Provide internet to private companies only
   b) Digitally connect all Gram Panchayats and villages in India
   c) Replace copper cabling with coaxial cables
   d) Launch satellites for broadband

Fill in the Blanks:

1. A _____ is an interconnection of computers and devices to enable communication and resource sharing.
2. In _____ networks, all devices act as equals without a central server.
3. The loopback IP address is _____, used for local testing.
4. A _____ is used to attach an RJ-45 connector to an Ethernet cable.
5. The most efficient type of charge controller for solar systems is _____.

Notes

3. Preventive Maintenance of Optical Network Terminal (ONT) Components

Telecom Sector Skill Council

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Key Learning Outcomes

By the end of this module, the paricipants will be able to:

1. Explain the history of fiber optics and its evolution as a communication medium.
2. Analyze the advantages and disadvantages of optical fiber compared to traditional copper cabling.
3. Identify the main components of an optical fiber and describe the function of each (core, cladding, coating).
4. Differentiate between various optical fiber types based on their refractive index profiles and propagation modes.
5. Describe the principles of light transmission within an optical fiber, including Snell's Law and the concept of Critical Angle.
6. Understand key transmission impairments in optical fiber, such as dispersion (modal and chromatic), attenuation (loss), and noise.
7. Explain how light is generated for optical communication, including the working principles of LEDs and Lasers, and their respective applications.
8. Define key optical phenomena such as polarization and interference as they relate to optical communication.
9. Summarize the characteristics of optical radiation and the role of optical light guides in transmitting data.

UNIT 3.1: Fiber Optics Overview

Unit Objectives

By the end of this unit, the participants will be able to:

1. Discuss the history of fiber optics and its key milestones.
2. Analyze the advantages and disadvantages of optical fiber as a communication medium.
3. Identify the major international standards governing optical fiber specifications.

3.1.1 History of Fiber

The concept of transmitting images and light through flexible glass fibers dates back to the 1930s. However, the practical application of optical fibers for telecommunications was not feasible until significant technological advancements were made. The invention of the first efficient light source, the laser, in the 1960s was a critical step.

Early in the 1970s, the primary obstacle was the high transmission loss of the optical fiber itself. Light signals would attenuate rapidly, severely limiting the practical transmission distance. To overcome this, scientists developed a revolutionary glass fiber structure consisting of a highly pure inner glass core surrounded by a lower-refractive-index glass cladding. The core guides the light, while the cladding prevents light leakage by using Total Internal Reflection to reflect the light back into the core.

Since then, optical fiber technology has advanced dramatically. Today, optical fibers, which are as thin as a human hair and made of glass or plastic, are the backbone of modern communication networks. They are used to transmit voice, video, and data signals across a wide variety of applications, from telecommunications and broadcasting to medical and industrial fields.

3.1.2 Advantages and Disadvantages of Optical Fiber

Advantages

- **High Bandwidth:** Optical fibers offer a much greater bandwidth than any other transmission medium. The amount of information that can be transmitted per unit of time is its most significant advantage, with high-performance single-mode fibers providing bandwidth that exceeds current and future application demands.
- **Low Power Loss:** Fiber optic cables have very low signal attenuation, which allows for extremely long-distance transmission. For instance, the longest recommended copper distance in an Ethernet network is about 100 meters, whereas fiber networks can extend for several kilometers (e.g., up to 40 km or more in some cases) without needing signal regeneration.
- **Immunity to Interference:** Optical fibers are made of dielectric materials, making them completely immune to electromagnetic interference (EMI) and radio-frequency interference (RFI). This allows them to be deployed in electrically noisy environments without affecting signal integrity.

- **Security:** Fiber optic cables are inherently secure. They do not radiate electromagnetic energy, making it virtually impossible to "eavesdrop" by tapping into the signal without physically cutting or splicing the fiber. Any physical attempt to tap the fiber is easily detectable through monitoring signal loss.
- **Small Size and Weight:** Fiber optic cables are significantly smaller, thinner, and lighter than copper cables with the same data capacity. This makes them easier to handle, transport, and install, and they occupy less space in conduits and cable trays.
- **Safety:** Optical fibers are made of glass or plastic and do not conduct electricity, eliminating the risk of electrical shock, short circuits, or sparks.
- **Durability:** Fibers have higher tensile strength than copper wires of a comparable diameter and are resistant to corrosive elements, which is a common problem with copper.
- **Cost-Effectiveness:** In long-haul, high-capacity applications, the cost per bit of data transmission is significantly lower for optical fiber than for copper, despite the higher initial installation costs.
- **Scalability:** The capacity of a fiber optic network can be easily upgraded by replacing the terminal equipment at the ends of the fiber without changing the physical fiber itself. Technologies like Dense Wavelength Division Multiplexing (DWDM) allow multiple channels of data to be transmitted simultaneously using different wavelengths of light, exponentially increasing the fiber's capacity.
- **Low Bit Error Rate (BER):** Due to their immunity to electromagnetic interference and other signal disruptions, optical fibers have an extremely low bit error rate, typically around 10−13.

Disadvantages

- **High Initial Cost:** While the cost of fiber optic cables has decreased, the initial installation cost, including specialized equipment and labor, remains higher than that of copper wiring.
- **Fragility to Bending**: Optical fibers are sensitive to sharp bends and can easily break or experience significant signal loss if bent beyond their recommended bend radius. This is mitigated by encasing the fibers in protective sheaths and strength members, which make the overall cable much more robust.
- **Specialized Tools and Skills:** Installation and maintenance of fiber optic networks require specialized and expensive tools, such as fusion splicers and Optical Time Domain Reflectometers (OTDRs). Technicians must also have specific training and expertise in handling and working with fiber optic cables.
- **Physical Damage Vulnerability:** While robust, fiber optic cables can still be damaged during construction or by environmental factors. Because a single fiber can carry a massive amount of data, damage to a cable can disrupt services for a large number of people, necessitating robust protection, redundancy (e.g., ring topologies), and rapid restoration plans.
- **Wildlife Damage:** Fiber cables are susceptible to damage from wildlife, including rodents and insects that chew on them, and birds that use them as nesting material. In some cases, tree roots have been known to grow around and constrict buried cables.

3.1.3 Optical Fiber Standards

Optical fiber standards are essential for ensuring interoperability and performance across different manufacturers and network systems. Key international standards are provided by organizations like the ITU-T, Telcordia, IEC, and TIA/EIA.

ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) Standards:

- **ITU-T G.651:** Specifies multimode fiber, which is used for shorter-distance applications due to its higher modal dispersion.
- **ITU-T G.652:** The standard for standard single-mode fiber (SSMF). It has four subcategories (A, B, C, D) that differ mainly in their water peak attenuation around the 1383 nm window, which is critical for long-haul and DWDM systems. This is the most widely deployed fiber type.
- **ITU-T G.653:** Defines Zero Dispersion Shifted Fiber (ZDSF), which has zero dispersion at the 1550 nm window. It is not widely used today due to its susceptibility to a nonlinear effect called Four-Wave Mixing in DWDM systems.
- **ITU-T G.654:** Specifies Cut-off shifted and low attenuation fiber, designed for very long-haul, high-capacity submarine applications where minimal loss is the top priority.
- **ITU-T G.655:** Defines Non-Zero Dispersion Shifted Fiber (NZDSF). This fiber type has low, but non-zero, dispersion in the 1550 nm and 1625 nm windows, which are used for DWDM. The non-zero dispersion helps to mitigate Four-Wave Mixing.
- **ITU-T G.656:** Specifies Medium Dispersion Fiber (MDF), designed for local access and long-haul networks where non-zero dispersion is desired.
- **ITU-T G.657:** A newer standard specifically for Fiber-to-the-Home (FTTH) applications. It is designed to be highly resistant to bending, with a small bend radius of 10 mm and 7.5 mm, making it ideal for in-building installations.

Other standards bodies, such as the Fiber Optic Association (FOA) and the Telecommunications Industry Association (TIA/EIA), also provide technical standards and guidelines for fiber optic components, testing, and installation.

Notes

UNIT 3.2: Light in Fiber

Unit Objectives

By the end of this unit, the participants will be able to:

1. Describe the fundamental structure of an optical fiber.
2. Explain the physical properties of glass as a transmission medium.
3. Compare the transmission capacity of optical fiber with other media.
4. Differentiate between various fiber refractive index profiles.

3.2.1 Fiber Structure and Light Propagation

An optical fiber is essentially a waveguide for light, with its basic working principle being Total Internal Reflection (TIR). The fiber cable consists of an inner cylinder called the core and a surrounding layer called the cladding.

- **Refractive Index (RI):** The core is made of a material with a higher refractive index (n1) than the cladding's refractive index (n2). When light travels from a medium with a higher refractive index to a medium with a lower one, it bends away from the boundary.
- **Total Internal Reflection:** When the angle of incidence of the light ray at the core-cladding boundary exceeds a specific threshold known as the critical angle, the light is completely reflected back into the core. This phenomenon ensures that the light signal remains contained within the core and propagates along the entire length of the fiber.
- **Wavelengths:** Optical fibe**Light Propagation Characteristics:**
- r communication systems typically operate in the infrared (IR) region of the electromagnetic spectrum, with wavelengths in the micrometer range (corresponding to frequencies from 1014 Hz to 1015 Hz).
- **Refraction and Reflection:** In a uniform medium, light travels in a straight line. When it encounters an interface between two different media, its direction changes. This change of direction is called refraction. At the same time, a portion of the light is reflected back into the original medium.
- **Snell's Law:** The laws of reflection and refraction, including Snell's Law ($n1\sin\theta1=n2\sin\theta2$), are the foundation of geometrical optics and describe how light rays behave at interfaces. Total Internal Reflection is a special case of refraction governed by these laws.

3.2.2 Fiber Glass as a Medium

Optical fibers are made from highly pure glass (typically fused silica, $SiO2$). The purity of the glass is critical to minimizing signal loss.

Optical Fiber Dimensions:

International standards govern the dimensions of optical fibers to ensure compatibility between different components and manufacturers.

- **Cladding Diameter:** The outer diameter of the cladding is a standard 125 micrometers (µm).
- **Coating Diameter:** The protective outer coating is typically 245 µm.
- **Core Diameter:** The diameter of the core varies by fiber type:
  - **Single-Mode Fibers:** Have a very small core, typically 8 to 10 µm.
  - **Multimode Fibers:** Have a much larger core, typically 50 to 62.5 µm in diameter.

3.2.3 Transmission Capacity

Optical fiber has an exceptionally high transmission capacity compared to other communication media. The table below provides a comparison of typical maximum bandwidths.

Technology	Maximum Bandwidth
Fiber Optics	>100 Gbps (with DWDM)
Cable Modems (DOCSIS 3.1)	1-10 Gbps
VDSL	50-100 Mbps
ADSL	9 Mbps
HDSL/E1	2 Mbps
ISDN PRI	2 Mbps
Satellite	~155 Mbps
Microwave	~155 Mbps
Wi-Fi (802.11ac/ax)	1-10 Gbps (in practice)
Ethernet (1 GbE)	1 Gbps
Analog Modem	56 Kbps

Fiber's capacity can be massively expanded using technologies like Dense Wavelength Division Multiplexing (DWDM), which allows multiple channels (each at a different wavelength of light) to be sent down a single fiber, leading to terabits per second (Tbps) data rates.

3.2.4 Fiber Refractive Index Profiles

The refractive index profile is a graphical representation of the distribution of the refractive index across the cross-section of an optical fiber. This profile is a key determinant of the fiber's transmission characteristics, particularly its performance concerning dispersion.

There are two primary refractive index profiles:

- Step-Index Profile: In a step-index fiber, the core has a uniform refractive index (n1) from its center to its outer edge. At the core-cladding boundary, the refractive index drops suddenly to a lower, uniform value (n2).
  - Characteristics: This profile is found in most single-mode fibers and some multimode fibers. The abrupt change in the refractive index leads to significant modal dispersion in multimode fibers, where different light rays (modes) travel different path lengths.
  - Parameters: A step-index fiber is defined by the core and cladding refractive indices (n1 and n2) and the radii of the core (a) and cladding (b). The fractional refractive index change is given by $\Delta=n1n1-n2$.
  - Pulse Dispersion: The pulse dispersion in a step-index multimode fiber is given by $\Delta\tau\approx cn1L\Delta$, where L is the fiber length and c is the speed of light.
- Graded-Index Profile: In a graded-index fiber, the refractive index of the core is highest at the center and gradually decreases toward the core-cladding boundary. This creates a parabolic or power-law profile.
  - Characteristics: This profile is used exclusively in multimode fibers to reduce modal dispersion. Light rays that travel a longer, zig-zag path in the outer part of the core move faster due to the lower refractive index, allowing them to arrive at the same time as rays traveling a shorter path near the center. This "corrects" the timing differences between modes.

Notes

UNIT 3.3: Light Propagation and Related Losses

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the concept of polarization and its impact on optical communication.
2. Describe the phenomenon of interference and its minimal effect on optical fibers.
3. Analyze chromatic dispersion, its causes, and its effects on signal integrity.
4. Differentiate between various propagation modes in optical fiber.
5. Apply Snell's Law and the concept of Critical Angle to understand light guidance.
6. Explain the different types of dispersion and their impact on a fiber's bandwidth.
7. Define noise and loss, and identify the primary mechanisms of signal attenuation in optical fiber.

3.3.1 Polarization

A beam of light consists of two mutually orthogonal vector fields: an electric field and a magnetic field, which oscillate perpendicular to the direction of propagation. Polarization describes the orientation of these fields. Light is considered polarized when the electric and magnetic field vectors have a specific, non-random orientation.

- Types of Polarization: Polarization can be classified as linear, circular, or elliptical, based on the pattern traced by the electric field vector over time. Linear polarization is the simplest case where the electric field oscillates along a single line.
- Impact on Fiber Optics: Polarization can be a significant issue in fiber optic transmission, particularly in high-speed, long-distance systems. It is characterized by several measurable properties:
    - Degree of Polarization (DOP): The ratio of polarized light intensity to the total light intensity. A DOP of 1 indicates fully polarized light, while a DOP of 0 indicates unpolarized light.
    - Polarization Extinction Ratio (PER): Expressed in dB, this is the ratio of the minimum to maximum polarized power.
    - Polarization Dependent Loss (PDL): The variation in signal loss as the input polarization changes. This is a common impairment in optical components.
    - Polarization Mode Dispersion (PMD): This is a form of modal dispersion that occurs in single-mode fiber. A single-mode fiber technically supports two orthogonal polarization modes. Due to imperfections in the fiber's core shape (non-circularity) and external mechanical stresses (bending, twisting), these two modes travel at different speeds. The resulting difference in propagation time, known as Differential Group Delay (DGD), causes the light pulse to spread. PMD is a time-varying property of the fiber, and the DGD values follow a Maxwellian distribution.

3.3.2 Interference

In physics, interference is a phenomenon where two or more waves superpose to form a resultant wave of greater, lesser, or equal amplitude. This effect is observed in all types of waves, including light, sound, and water waves. In traditional copper-based electrical networks, interference is a significant problem caused by the electromagnetic fields generated by current flow, which can be affected by nearby electrical or magnetic fields, leading to signal distortion and attenuation.

In optical fiber, however, the signal is transmitted using light, and the fiber itself is made of dielectric materials (glass or plastic). This makes it immune to electromagnetic interference from external sources. The core, where the signal travels, is protected by the cladding and an outer buffer, preventing extraneous light signals from interfering. Therefore, interference does not occur in optical fibers in the same way it does in metal wires.

3.3.3 Chromatic Dispersion

Chromatic Dispersion (CD) is a major concern in high-speed fiber optic communication. It is a phenomenon where different wavelengths (or "colors") of light within a pulse travel at different speeds through the fiber, causing the pulse to spread out over time. This pulse broadening can lead to inter-symbol interference, which limits the maximum data rate of a system.

Causes of Chromatic Dispersion:

- Material Dispersion: The refractive index of the fiber's material (glass) is dependent on the wavelength of light. This causes different wavelengths to travel at different velocities, leading to pulse spreading.
- Waveguide Dispersion: The distribution of light energy between the core and the cladding is dependent on the wavelength. Since the core and cladding have different refractive indices, different wavelengths travel at slightly different effective speeds. This is a significant factor in single-mode fibers.

Effects of Chromatic Dispersion:

- Pulse Broadening: The most direct effect is that a narrow input pulse will broaden into a wider output pulse, which can cause it to overlap with adjacent pulses.
- Chirping: Dispersion can cause different frequency components of a pulse to arrive at different times, a phenomenon known as "chirping."

Chromatic dispersion is measured by the chromatic dispersion coefficient, typically in units of ps/(nm·km). It can be minimized by using high-quality light sources with narrow spectral widths (like lasers) and by designing fibers to have a specific dispersion profile.

3.3.4 Propagation Modes

In an optical fiber, a mode refers to a specific path that a light ray can take as it travels down the fiber. The number of modes that a fiber can support depends on its physical dimensions and the refractive index profile.

TE and TM Modes: Electromagnetic waves in an optical fiber have both electric and magnetic field components. Transverse Electric (TE) modes have an electric field that is perpendicular to the direction of propagation, while Transverse Magnetic (TM) modes have a magnetic field perpendicular to the direction of propagation.

Two Main Types of Fiber Based on Modes:

1. Single-Mode Fiber (SMF):

- **Structure:** Has a very small core diameter (8-10 µm) that is only slightly larger than the wavelength of light being transmitted.
- **Propagation:** The small core size allows only a single mode of light to propagate down the fiber.
- **Characteristics:** Because there is only one path, single-mode fiber has virtually no modal dispersion. This allows for extremely high bandwidth and is ideal for long-haul applications (over 100 km). SMF is more expensive to manufacture and requires precise alignment during splicing and connection.

2. Multimode Fiber (MMF):

- **Structure:** Has a much larger core diameter (50 or 62.5 µm).
- **Propagation:** The large core allows multiple modes of light to propagate simultaneously.
- Characteristics: MMF is more susceptible to modal dispersion, where different light paths cause the pulse to spread out. This limits its bandwidth and effective transmission distance. However, it is less expensive than SMF and is easier to work with, making it suitable for local area networks and short-distance premise applications.

There are two types of multimode fibers based on their refractive index profile: step-index multimode fiber (higher modal dispersion) and graded-index multimode fiber (much lower modal dispersion).

3.3.5 Snell's Law

Snell's Law is a fundamental principle of optics that describes the relationship between the angles of incidence and refraction when a light wave passes from one medium to another. The law is given by the **formula:**

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

Where:

- n_1 and n_2 are the refractive indices of the first and second media, respectively.
- θ_1 is the angle of incidence.
- θ_2 is the angle of refraction.

This law is crucial for understanding how light is guided within an optical fiber. When light travels from the fiber core (denser medium, n_1) to the cladding (less dense medium, n_2), it is refracted.

3.3.6 Critical Angle and Total Internal Reflection

- Critical Angle (θ_c): When light travels from a denser medium to a less dense medium, the refracted ray bends away from the normal. As the angle of incidence increases, the angle of refraction also increases. The critical angle is the specific angle of incidence at which the refracted ray reaches an angle of 90 degrees and travels along the boundary of the two media.
- Total Internal Reflection (TIR): If the angle of incidence is greater than the critical angle, the light ray cannot escape and is completely reflected back into the original, denser medium. This principle of TIR is the very foundation of how optical fibers work, guiding light along their core.

3.3.7 Dispersion

Dispersion in optical fiber is the phenomenon where the different components of a light pulse (e.g., different wavelengths or propagation modes) travel at different speeds, causing the pulse to broaden. This pulse spreading is the main factor that limits the bandwidth of an optical fiber link.

The three primary types of dispersion are:

- **Modal Dispersion:** Occurs only in multimode fibers. Different light rays (or modes) take different path lengths down the fiber, causing them to arrive at the destination at different times.
- **Material Dispersion:** A form of chromatic dispersion caused by the material's refractive index being dependent on the wavelength.
- **Waveguide Dispersion:** A form of chromatic dispersion caused by the geometry of the fiber. It occurs because the energy of the light signal is not entirely confined to the core but is distributed between the core and cladding. Since the core and cladding have different refractive indices, different wavelengths have different velocities.

3.3.8 Noise and Loss

Noise is any unwanted signal that corrupts the original information-carrying signal, especially at low power levels. It can be categorized as intrinsic (from the system itself) or extrinsic (from external sources). In optical communication, noise can come from the light source, the detector, and various system components.

Loss (Attenuation) is the reduction in the power of the optical signal as it propagates along the length of the fiber. This exponential power reduction is a key design consideration for any fiber optic link.

Key Fiber Loss Mechanisms:

- Rayleigh Scattering: A wavelength-dependent loss caused by microscopic density fluctuations and compositional inhomogeneities in the glass, which are a result of the manufacturing process. It accounts for a significant portion of the total loss.
- Absorption: Loss that occurs when the light energy is converted into other forms, such as heat.
    - o Intrinsic Absorption: Caused by the fundamental properties of the silica glass itself in the ultraviolet and infrared regions.
    - o Extrinsic Absorption: Caused by impurities in the glass, with water molecules (hydroxyl ions, OH-) being the most significant culprit. These impurities cause prominent absorption peaks at specific wavelengths (e.g., 950 nm, 1250 nm, and 1380 nm).
- Macroscopic Bends: Losses caused by large-scale bends in the fiber during installation. Light that hits the core-cladding boundary at an angle less than the critical angle escapes.
- Microscopic Bends: Losses caused by tiny, random bends in the fiber geometry due to non-uniform pressure from the surrounding jacket.
- Nonlinear Scattering: At high optical power levels, nonlinear effects like Stimulated Brillouin Scattering (SBS) and Stimulated Raman Scattering (SRS) can occur, leading to significant signal loss and distortion.

Notes

UNIT 3.4: Optical Sources

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the fundamental principles of light production in various mediums.
2. Describe the characteristics and applications of Light Emitting Diodes (LEDs) in optical communication.
3. Understand the working principle and advantages of Lasers in fiber optic systems.
4. Recognize the role of fiber optic light guides and their different types.
5. Define optical radiation and its classification within the electromagnetic spectrum.

3.4.1 Light Production

At the most fundamental level, light is produced when an electron transitions from a high-energy state to a lower-energy state within an atom, molecule, or solid material. The energy difference between these two states is emitted as a photon—a discrete packet of electromagnetic energy.

Spontaneous Emission vs. Stimulated Emission

- **Spontaneous Emission:** When electrons are excited into higher energy states (either thermally, electrically, or optically), they typically return to their lower-energy ground state spontaneously, emitting light randomly in time and direction. This is the underlying mechanism for traditional light sources such as incandescent bulbs and fluorescent lamps.
- **Stimulated Emission (Key to Lasers):** In certain materials and conditions, an incoming photon can induce an excited electron to drop to a lower energy state, releasing a second photon with identical phase, frequency, and direction. This coherent light amplification process is essential in laser operation. The excited state can remain populated for microseconds, providing a window for stimulated emission to occur before spontaneous relaxation dominates.

Energy Excitation Methods

- **Heat (Thermal Excitation):** Thermal energy raises electrons to excited states. The classical example is incandescent light bulbs, where a heated filament emits a broad spectrum of light as electrons return to lower states randomly, producing incoherent, broadband light.
- **Electrical Discharge (Gas Discharge):** An electric current passed through a low-pressure gas (e.g., neon in neon lamps) causes ionization, freeing electrons and raising them to excited states. As these electrons recombine with ions, photons are emitted, producing fluorescent or discharge lamps.
- **Electrical Current in Semiconductors (Electroluminescence):** When a forward voltage is applied across a p-n junction in a semiconductor, electrons from the n-type region recombine with holes in the p-type region. This transition results in photon emission in LEDs and laser diodes. Depending on the device design, the emission can be spontaneous (LED) or coherent and stimulated (Laser).

Classification of Spontaneous Emission Sources

Term	Description
Radiant Light	Light emitted due to heating (thermal emission).
Fluorescence	Light emission occurs while an external energy source is present; stops quickly after energy source removal.
Phosphorescence	Emission continues for some time after the energy source is removed.

3.4.2 Light Emitting Diodes (LEDs)

Semiconductor materials form the core of most optical sources used in telecommunications due to their compact size, reliability, and efficiency.

Design Challenges of LED Light Sources

1. **Coupling Light into Optical Fiber:**
   - Surface Emitting LED (SLED): Emits light perpendicular to the surface of the semiconductor.
   - Edge Emitting LED (ELED): Emits light from the side, which can be easier to couple into the optical fiber core.
2. **Confined Light within the Device:**
   - The active layer is sandwiched between materials of lower refractive index to create an optical waveguide, effectively confining photons to the active region and directing them towards the fiber.
3. **Power Delivery to Active Region:**
   - Electrons and holes are injected via electrodes into the active region to facilitate recombination and photon generation.
4. **Heat Management:**
   - LEDs generate heat, which needs to be dissipated using heat sinks or other thermal management techniques to maintain performance and prevent damage.

Light Coupling Techniques

1. **Graded-Index (GRIN) Lens:**
   - A GRIN lens is a short length of graded index optical fiber, with a gradually changing refractive index, used to focus light from an LED onto the fiber core.
2. **Ball Lens Coupling:**
   - A spherical lens (ball lens) is attached to the LED surface with epoxy resin (having a specific refractive index) to help focus the light, though mismatches in refractive index between the semiconductor (~3.5), the fiber (1.45), and the epoxy can cause losses.
3. **Direct Coupling:**
   - The optical fiber end is placed in direct physical contact with the LED, often housed in a connector assembly. This method is low-cost, simple, and widely used, despite lower coupling efficiency compared to more precise optical alignment techniques.

4. Ball Lens on Fiber End:

A ball lens is attached directly to the fiber end to focus and couple light efficiently.

LED Characteristics:

- Low Cost: LEDs are typically cheaper than laser devices in terms of manufacturing, though their performance differs.
- Low Power Output: Typical output power is around 100 microwatts, though recent advancements have achieved outputs of up to 75 milliwatts.
- Spectral Width: LEDs produce broadband light, typically spanning 50 to 100 nm spectral width, unlike lasers that are narrowband.
- Incoherent and Non-Directional Light: Because of incoherent emission, lenses are needed to focus light into multimode fiber. Single-mode fiber coupling is not practical due to small core diameter (~9 µm).
- Digital Modulation Limitations: LEDs are limited in modulation speed and are suitable for data rates up to approximately 300 Mbps. Gigabit speeds typically require laser sources.

3.4.3 LASER (Light Amplification by Stimulated Emission of Radiation)

Working Principle:

The laser operates based on two fundamental phenomena:

- Population Inversion: An external energy source excites electrons into higher energy states, creating a condition where more electrons occupy excited states than ground states.
- Stimulated Emission Process: A photon with energy matching the energy gap between excited and ground state stimulates the excited electron to emit a second photon identical in phase, frequency, and direction to the incoming photon.

This results in coherent, highly directional, monochromatic light ideal for telecommunications.

Laser Types Used in Telecommunications

- Fabry-Pérot (FP) Lasers: Common in cost-sensitive applications.
- Distributed Feedback (DFB) Lasers: Provide narrow linewidth, useful for long-distance communication.
- Vertical-Cavity Surface-Emitting Lasers (VCSEL): Compact, efficient, suited for short-distance links.

3.4.4 Fiber Optic Light Guides

Fiber optic light guides transmit light from an external source to devices such as microscopes, imaging systems, or endoscopes.

Types of Light Guides

- Back-Lights: Distribute light uniformly from the back surface.
- Ring Lights: Provide even illumination around an object for microscopy or photography.

Advantages of Fiber Optic Light Guides

- Single light source powering multiple output adapters.
- Efficient coupling reduces cost compared to multiple separate light sources.
- Flexibility in directing light over long distances with minimal loss.

Type	Features and Applications
General Purpose Illuminators	Use step-down transformers to supply regulated 21V to lamps. Common in stereo microscopy.
AC Stabilized Illuminators	Stabilization circuits reduce line voltage fluctuation; soft-start extends lamp life. Used in photography and non-critical illumination applications.
AC/DC Regulated Illuminators	Provide highly stable output voltage, reducing lamp degradation. DC models especially suitable for machine vision where stable light intensity is crucial. Often support remote control.

3.4.5 Optical Radiation

Optical radiation refers to electromagnetic radiation in the wavelength range of 100 nm to 1 mm, encompassing:

Range	Wavelength (nm)	Designation
Ultraviolet (UV)	100 – 400	UV-A (315–400 nm), UV-B (280–315 nm), UV-C (100–280 nm)
Visible Light (VIS)	400 – 800	Perceptible by the human eye
Infrared (IR)	800 – 1,000,000	IR-A (800–1400 nm), IR-B (1400–3000 nm), IR-C (3000 nm – 1 mm)

These electromagnetic waves obey the classical laws of optics such as reflection, refraction, and diffraction. Optical radiation plays a key role in fiber optic communication, illumination, and sensing.

Notes

UNIT 3.5: Gigabit Capable Passive Optical Network (GPON)

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the fundamental principles of light production in various mediums.

3.5.1 GPON

A point to multi point architecture can be implemented by using Passive optical telecommunication technology, where a single fiber optic cable is using to provide signals from centre point to a node in which a passive element like splitter will provide services to multiple terminals or customers.

Gigabit Capable Passive Optical Network (GPON) technology node is the access necessary to deliver multimedia services (voice, data, video and other content-content) for residential and business customers.

GPON-based FTTx technology below:

- FTTH (Fiber to the Home)
- FTTB (Fiber to the Building)
- FTTZ (Fiber to the Zone)
- FTTT (Fiber to the Tower)
- FTTC (Fiber to the Curb)

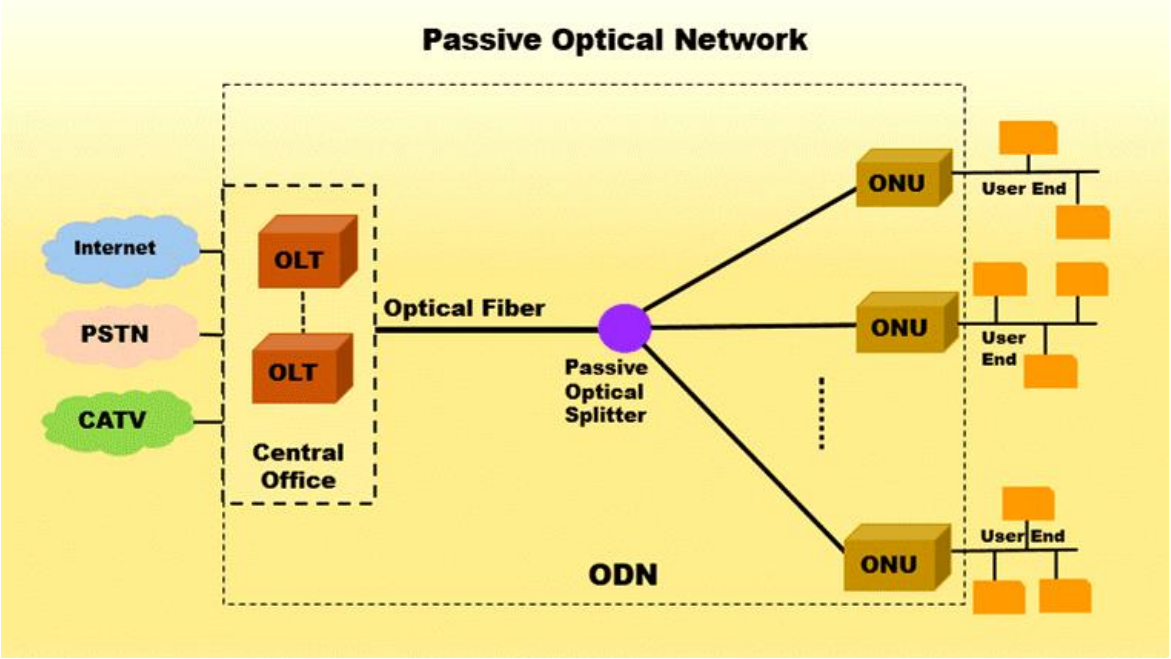


Fig. 3.5.1. PON Technology Architecture

By introducing new PON architecture, we can reduce the amount of optical fiber used and central office infra equipment compared with point-to-point (P-to-P) architecture. A passive optical network is same as of fiber-optic access network. There could be one or multiple telecom vendors provide the input service lines for OLT (Optical line terminal)

Refer Fig 3.5.1 & 3.5.2 GPON system role out in the access technology market to provide triple-play services to the home\business customers. Triple play services include Voice, Video and Data. The First deployed system was based on ATM-PON(A -PON), then Broadband PON (B-PON) and Ethernet- based PON (E-PON), but the BPON can only deliver a speed up to 1244.16 Mbps in downlink stream while EPON systems could deliver 1.25 Gbps. Emerging high bandwidth applications such as HDTV service are rolling out, and those PON networks only can provide required bandwidth. To make out this, G.984 specifications introduced by ITU-T, this defined GPON operations.

GPON consists of OLT, ONT, and Splitters & CCU- SPV. It was the next-generation of PON network. GPON supports much more data rates and bandwidth than that of previous PON technologies. Also GPON exhibits symmetric and asymmetric architecture. GPON supports upstream and downstream data rates of 2.5 Gbps each and it can be reach out a distance of 60km radius with supporting 32, 64 or maximum 128 users per a single interface. GPON is the technology of option to deploying FTTx by the telecom firms; GPON could deliver much better Quality of Service (QoS), higher bandwidth and enhanced scalability when it's compared to previous Passive Optical networks.

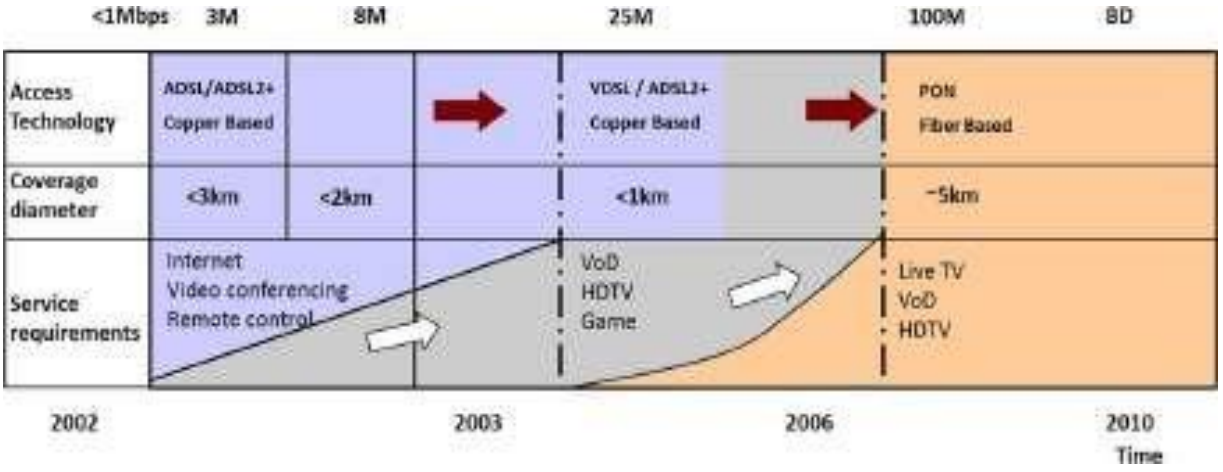
OLT is worked as a central office of service provider and it switch & Route the connection to end users by optical network units (ONUs) / Optical Network Terminals (ONTs) at (Gram Panchayats). In OLT signals transmitted combined to single fiber using WDM {Wavelength-division multiplexing} techniques. Transmission signals will consist of Voice and data parts, which use a wavelength of 1490 nm for downstream {towards users in Gram panchayaths} signals and the wavelength of 1310 nm for upstream signal {from User end to OLT}. From a satellite feed or from a cable television head end, Video services entered to the system. A wavelength of 1550nm is using to distribute (Downstream only). Video signals. OLT consists of SNI (Service Node Interface) - 10G & 1G Ethernet & UNI (User Node Interface) - E1, 10/100/1000 Base T, Telephony, analog video, USB etc. OLT and ONT use TDM/TDMA protocol. Single OLT communicate with Multiple ONT. OLT can be configured with Single Fiber or Dual Fiber for upstream & downstream. GPON OLT has the provision to taking care of card failure and fiber cuts etc.

Passive optical splitter, requires no maintenance and no power activation on ideal conditions. Splitters receive single input and split it to multiple users via different ports. Higher insertion loss is the primary drawback of splitters. Insertion loss can be illustrated as 10log (1/n), where value of n can be 2 to128 (n: number of ports). This insertion loss impacted highly on the transmission range of FTTH (fiber to Home), essentially limiting the achievable span length to a distance of approx. 20 Kms (maximum insertion loss of approximately 30dB). OLT transmitting power and ONT receiver sensitivity is defined keeping the splitter loss in considerations. Depending on the number of ports available, insertion loss of splitters will be varies.

Splitter insertion loss corresponds to the number of port shown in the table given below.

Number of Ports	Insertion loss
2	3 dB
4	6 dB
8	9 dB
16	12 dB
32	15 dB
64	18 dB
128	21 dB

The Below Table shows comparative reasons for choosing PON technology in Network.



PON - Key Elements:

- ODN (Optical Distribution Network): An ODN enables the distribution system to reach signals towards costumer premises from OLT and vice versa. This distribution system uses only passive optical devices.
- OLT (Optical Line Termination): OLT devices are endpoint node on the service provider side of PON system, and will be located in the central office.
- ONT (Optical Network Termination): ONT have multiple native ports and which terminates the PON network in customer side.
- ONU (Optical Network Unit): An ONU working same as ONT device, which terminate Passive Optical Network, and may consist multiple converged ports, such as XDSL or Ethernet, toward consumers. An ONU need a separate consumer hardware device to support native services such as telephony, video etc.

GPON Services:

- GPON can support Triple–play services. It can be good replacement of all the previous bandwidth limiting technologies.
- So it can be supports high- bandwidth transmission to so as to satisfy the requirements of IPTV and live TV broadcasts and all other high bandwidth services. One of the main feature of GPON is its Long coverage is almost up to 20km.
- GPON uses Twisted pair cables in the access technology to reduce the complexity and the number of nodes.
- GPON can be support integrated high bandwidth services by fully standardized and highly bandwidth supporting components

GPON Principle

Data Multiplexing:

GPON uses Wavelength division multiplexing (WDM) which facilitate communication in bi- direction through a single mode optical fiber. GPON has two multiplexing mechanism to distinguish upstream and downstream signals of individual user connections:

1. Broadcasting method in down-stream.
2. TDMA transmission technology in upstream.

Fig. 3.5.3 GPON - Data Multiplexing

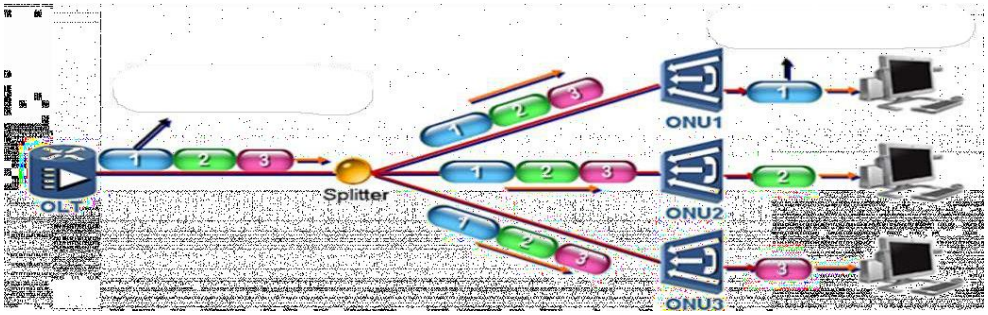


Fig. 3.5.4. GPON - Downstream Data

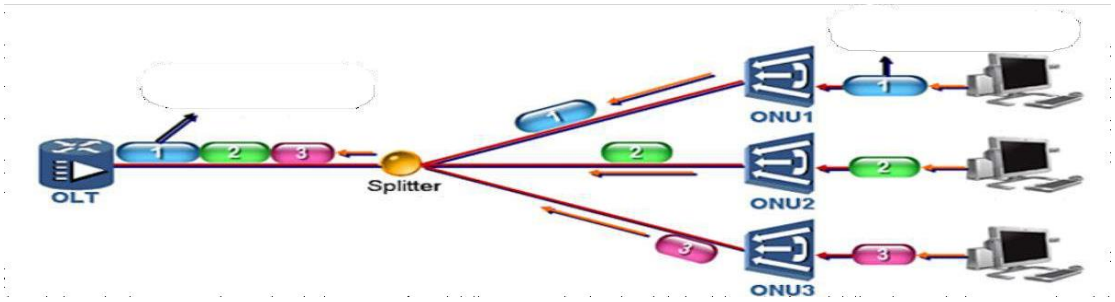


Fig. 3.5.5. GPON - TDMA Mode

GPON Standards

ITU-T G.984.1

1. Parameter description of GPON network
2. Requirements of protection switch-over networking

ITU-T G.984.3

- Specifications of TC layer in the GPON system
- GTC multiplexing architecture and protocol stack
- GTC frame
- ONU registration and activation
- DBA specifications
- Alarms and performance

ITU-T G.984.2

- Specifications of ODN parameters
- Specifications of 2.488Gbps downstream optical port
- Specifications of 1.244Gbps upstream optical port
- Overhead allocation at physical layer

ITU-T G.984.4

- OMCI message format
- OMCI device management frame
- OMCI working principle

GPON identifies 7 transmission speed combination as follows:

1. 0.15552 Gbit/s up, 1.24416 Gbit/s down
2. 0.62208 Gbit/s up, 1.24416 Gbit/s down
3. 1.24416 Gbit/s up, 1.24416 Gbit/s down
4. 0.15552 Gbit/s up, 2.48832 Gbit/s down
5. 0.62208 Gbit/s up, 2.48832 Gbit/s down
6. 1.24416 Gbit/s up, 2.48832 Gbit/s down

7.2.48832 Gbit/s up, 2.48832 Gbit/s down

Among them, 1.24416 Gbit/s up, 2.48832 Gbit/s down is the mainstream speed combination supported at current time.

- Maximum logical reach: 60 km
- Maximum physical reach: 20 km
- Maximum differential fibre distance: 20 km
- Split ratio: 1 : 64, it can be up to1 : 128

GPON Device & Features

GPON OLT & ONT consists elements as follows

- OLT (Optical Line Terminal Equipment)
- ONT (Optical network terminal Equipment)
- SPL (Splitters Equipment)
- CCU (Charge Coupler Unit) & SPV (Solar Photo Voltaic Equipment)

OLT

OLT receives the service input from BBNL /BBNL vendor .OLT downstream the data through splitters and reach to multiple ONT. ONT provides services to the end Users. ONT is powered up by CCU & SPV.

GPON OLT (UTL) Consist of below functional elements

- PON Interface Card
- SCM
- PDU
- MOTHER BOARD

Fig. 3.5.6. UTL OLT

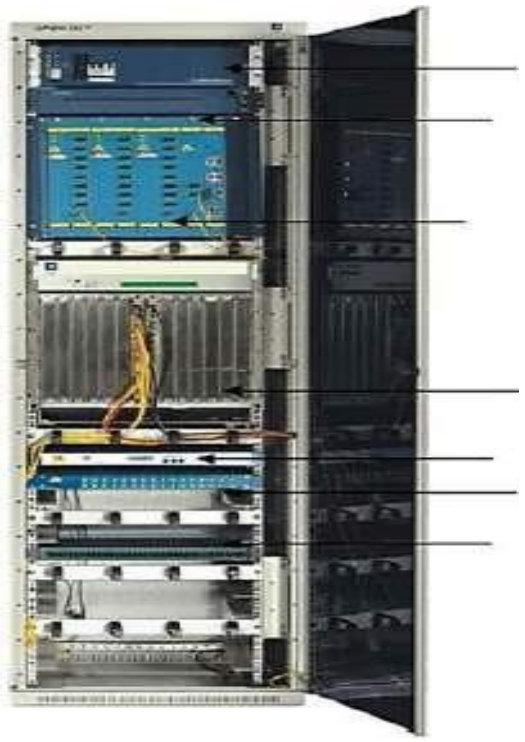


Fig. 3.5.7 GPON -OLT Model

PON Interface Card (SCM) :

- PIC acts as line card towards PON
- It provides a total of 4 PON interface
- In the upstream direction this card extracts 2.5G
- Ethernet data of each PON from GEM frame and sends two 10G Ethernet links, one each towards the two 10G SCM through back plane.
- Each SCM can have 1:1 protection on active stand by basis

Switch and Control Module (SCM):

- Main function of this module is to provide SNI (Service Node Interface) functions and to control GPON system.
- It provides 4 10G and 4 1G Ethernet uplinks at SNI.
- This module provides EMS & LCT interfaces of the OLT system. – B1 port for EMS & b2 port for LCT
- This module receives PON side Ethernet data through 10G Ethernet link via back plane - Single Pic card have 4 PON port - each PON port goes to 4 ONT via 1: 4 splitter and hencea PON card support till 32 ONT
- It has one 100mbps Ethernet link with all PIC for management purposes.

Features of OLT

1. Complaint with ITU-T G.984 & TEC-GR
2. 5 Gbps downstream at 1490nm
3. 1.25 Gbps upstream at 1310nm
4. RF video transmission at 1550nm(optional)
5. 48 unprotected PON ports supported per shelf
6. Can support 1:1 protection towards ODN (SCM card active stand By operation)
7. Can support up to 32 ONTs per PON port
8. Typical coverage distance supported is 20 km (could be extended by another Splitter)
9. Upto 1536 ONTs supported per shelf (considering 1:32 splitter , Single Pic Card support 128 ONT with considering all 12 PIC card result to 1536 ONT)
10. 1Provide 10Gb & 1Gb Ethernet uplinks for SNI
11. Maintain Synchronization of the GPON system through network clock
12. GPON OLT is standard telecom grade equipment. So all routine checks which are done on any other telecom equipment are also applicable for GPON system.

Application Modules

1. Configuration Management (CM)
2. Connection Management (CN)
3. Fault Management (FM)
4. Performance Management (PM)
5. Security Management (SM)
6. Software Download (SD)

Configuration Management

1. Configuration of ONT equipment
2. Configuration of the UNIs
3. Configuration of the OAM flows
4. Configuration of the physical ports
5. Configuration of the traffic descriptors
6. Configuration of Priority queues
7. ONT activation when it is new to OLT

Connection Management (CM)

1. Configuration of the GEM Port Network CTPs
2. Configuration of Inter working Termination points
3. Configuration of service profiles
4. Configuration of GAL profiles
5. MAC bridge service connection set-up
6. MAC bridge service connection tear-down
7. Addition of entries to MAC Filter Table
8. Removal of Entries from MAC Filter Table
9. It supports IPTV filtering

Fault Management (FM)

1. FM module resides in PIC card, ONT/ONU and SCM cards and it supports FM functions
2. All the alarms occurring in the GPON system are reported to the LCT/EMS with their date and time of occurrence, severity and likely cause
3. This module also maintains history alarms for the last 30 days.

This module is also responsible for generating alarm on loss of physical layer notification and laser shutdown.

Performance Management (PM)

1. PM module is responsible to collect and report performance monitoring data associated with a Monitored managed entity for the last completed 15 minute interval.
2. It collects Ethernet Performance Monitoring History data, TC Adaptor Protocol Monitoring Data, GEM Port Protocol Monitoring History Data, GAL Ethernet Protocol Monitoring History Data.
3. This module is also responsible for threshold crossing alert (TCA) notification

Security Management (SM)

1. SM module is provided to ensure authorized access. It resides in the SCM card of the OLT System. There are 3 levels of Security
2. Super: SM ensure that there is only super user. He will provide all the configuration data and will be able to modify and monitor the system completely. He has the privilege of adding and deleting the users and modify the privileges of users
3. Privileged: This user has access to certain privileged commands. He will not have access to critical features of the system. He can view all the information related to any NE for remote supervision from any other NE or through internet
4. Ordinary: This user is able to view only system reports and status of specific NE from its local management I/f.

System Management Interfaces

1. System management has been provided through two standardized interfaces:
    - Local Management Interface: The local manager is able to install, monitor, control and configure the GPON system.
    - EMS Interface: A GUI based Element Management System is provided to control and monitor the GPON system. This EMS interacts with the GPON system using standard SNMP V3 protocol.
    - The EMS is able to support all the functions like Operation, Administration, and Maintenance.

Following should be taken up for routine maintenance :

1. Equipment Room Temperature Check 2
2. Power Voltage (-48V DC power supply) Check
3. PDU (Power Distribution Unit) Status Check
4. Fan Tray Status Check
5. Dust-Filter Check
6. SCM Card Status Check
7. PIC Card Status
8. Backplane Status Check
9. ONT Status Check
10. CCU- SPV Status Check

Transmitter module- OLT

1. It is a externally modulated CATV fiber optic high performance 1550 nm transmitter
2. It is capable of coupling high optical powers with low optical line width.
3. It has in built adjustable SBS control and electronic dispersion compensation
4. This module has a built in DC power supply, front panel, optical splitter, network card and Necessary connectors

OLT Power Supply Specifications

1. Nominal Input Power Supply: -48V DC
2. Input Voltage Range: -40V DC to –60V DC

GPON ONT

Optical Network Termination (ONT) on the GPON side has fiber to interface with OLT and on other side it has supports various user interface like Gigabit Ethernet, POTS and RF video.

Fiber optic transmission technology is using to reach the signal to customer premise. Optical fiber technology is not providing electrical power for customer side equipments, nor it apt for direct connection to premise equipment. A converter device is used to terminate the fiber line. This device which is using in FTTx is called as Optical Network Terminal (ONT).This device will separate the original signal into its sub components like voice signal television and data signal. This device will de-multiplex. For the telephone operation this device will provide the power also. As the ONT have to take electrical power for the operation by the customer end power line, multi power backup option is available with ONTs, which helps to provide service during multi power failure.

ONT11 (UTL-ONT-72)- A UTL product System Overview

Fig. 3.5.8. ONT Location of the Network

Fig. 3.5.9. UTL-ONT Device by UTL

ONT11 is single card system, which is designed to serve an individual residential unit. ONT consumes 17 was (Approx.) power and operates on 12v DC power supply through AC/DC adaptor. ONT houses in a small metal box of size "220 x 188.9 x 48.6 (mm)" and can be placed on table top or mounted on wall.

The system provides access to users for voice, video and data services over single optical fiber. Small Family Unit (SFU) ONT is a single card system. - On the GPON side it has fibre to interface with OLT and on other side it has supports various user interfaces like Gigabit Ethernet, POTS and RF video. GPON I/f is 1.244 Gbps US at 1310 nm and 2.448 Gbps DS at 1490 nm for data and 1550 nm for Video. At user side there is one Gigabit Ethernet I/f, two POTS port and one analog video port.

ONT-Interfaces - ONT interfaces varies with ONT version and release. MDU-ONT is similar to SFU-ONT but has more number of user I/f. On the GPON side it has fiber to interface with OLT and on other side it has supports various user interfaces like Gigabit Ethernet, POTS and RF video. GPON I/f is 1.244 Gbps US at 1310 nm and 2.448 Gbps DS at 1490 nm for data and 1550 nm for Video.

At user side ONT provides

- 1 Gigabit Ethernet I/f
- 4 100 Base-T Ethernet
- 4 E1 ports
- 4 POTS port
- One analog video port

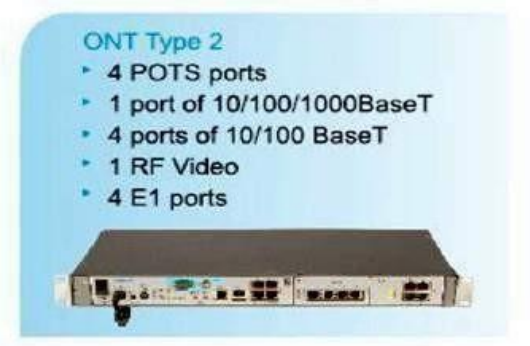


Fig. 3.5.10. ONT Type 2 Device

ONT type 11 Consist as follows:

- 2 POTS Ports
- 4port 1000 Base T
- 2 USB

Functions and Features of ONT

1. In Upstream direction

- ONT11 connects to OLT in the network through a passive optical network
- (PON) port to provide integrated access service.

2. In Downstream direction

- ONT11 connects with LAN Switches, PC, and STB etc. through Ethernet ports, to access data and video services.
- RJ11 ports are provided on ONT to connect phone or fax through POTS
- Interfaces for extending Voice and FAX services.

ONT11 is single card system, which is designed to serve an individual residential unit. ONT consumes 17 watts (Approx.) power and operates on 12V DC power supply through AC/DC adaptor. ONT houses in a small metal box of size “220 x 188.9 x 48.6 (mm)” and can be placed on table top or mounted on wall. The system provides access to users for voice, video and data services over single optical fiber.

ONT Serves as a GPON network termination at users end to support broadband connection and access to triple play services. It Supports GPON access and network connectivity up to 2.488 Gbit/s data rates in downstream and 1.244 Gbit/s data rate in upstream. ONT have four Ethernet ports (Tri rate 10/100/1000 Base-TX full-duplex) with RJ45 interface are provided on the ONT to extend all data and IP related services like Internet, IPTV, and VOD etc.

Two POTS ports are provided on ONT for Voice and FAX services through RJ-11connectors. One virtual interface is provided on the ONT to support VEIP services. Through VEIP ONT can be configured in RGW mode to support Wi-Fi access for multiple users. ONT provides web-based configuration through IE browser. ONT Software up-gradation is supported online remotely either through LCT or EMS.

PON Splitters:

Fig. 3.5.11. UTL - PON Splitter

Fig. 3.5.12. UTL - PON Splitter (PON Inside)

Parameter	Unit		
Type	-	1 X 4	1 X 8
Operating wavelength	Nm	1260-1360 / 1480-1580	
Insertion Loss	dB	≤ 7.1	≤ 10.5
Uniformity	dB	0.5	0.8
PDL (max)	dB	<0.2	<0.2
Return Loss / Directivity	dB	>55	>55
Fiber Type	Single mode fibre, G.652/G.657A		
Working Temperature	ºC	-40 to +85	

Fig. 3.5.13. UTL GPON Splitters Specification

Planar Light-wave Circuit (PLC) Splitters

Fiber optic splitters enable an optical signal to be distributed among multiple fibers outputs. Since splitters contain active electronic parts and do not require power. They are an integral component of the optical networks and widely used.

The diagram above refer to fig 6.2.1 & 6.2.2 shows how light from a single input fiber can split between four individual output fibers (1x4). A PLC splitter is made with techniques much similar to manufacture semiconductors. These optical splitters are very compact, efficient, and reliable.

Fiber optic terminal box helps to distribute and avoid mechanical damages of fiber optic links in FTTX generally refer to the box shape optical management product. Normally the fiber optic tool box consists of optical terminal box optical patch panels. Optical termination box is small in size and fiber patch panel is bigger.

Cable Management

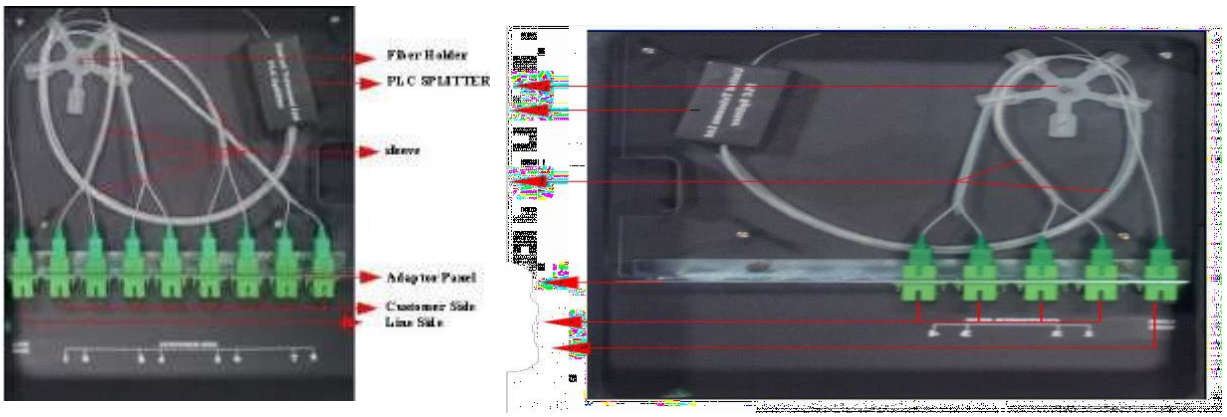


Fig. 3.5.14. Cable Management

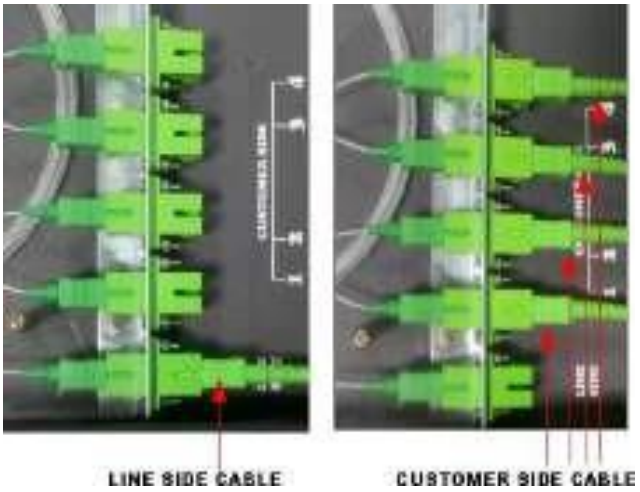


Fig. 3.5.15. 1:4 splitter

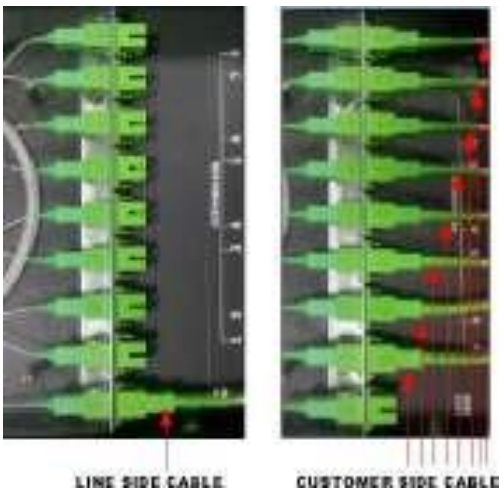


Fig. 3.5.16. 1:8 splitter

ONT in Gram panchayat's location keep the service alive with the help of multiple Power source. Power to ONT is derived from Ac mains, Solar Panel & battery bank. CCU- charge coupler unit consists of controller board, battery and serge boards for AC mains and Solar panel. UTL-SPV-018 “HYBRID SPV POWER SYSTEM FOR ONT”, is one single integrated switched mode power supply unit that is capable of working on both Single-phase AC Mains Input (90 – 300 VAC, 50Hz) as well as on 12V/60W Solar Photovoltaic (SPV) Panel output. A 12V/17Ah SMF VRLA Battery is fit inside the CCU cabinet itself. 12V/60W SPV Panel is Mounted on a Mounting structure either on Rooftop, Wall or on a Self-supporting Mast. The SPV panel is DC Power Generating System – the non- conventional source of power – that converts Solar Energy (Sun Light) directly into DC Power. The unit is protected against reverse polarity connection of SPV Panel to CCU. An LED indication is provided for this purpose on the front side of the unit. The CCU is designed and certified to confirm to EMI and RFI suppression as per IEC-CISPR 22 and IEC 61000-4 standards. When Both SPV Panel Power and Mains AC I/P is available, The ONT Load and the Battery charging Current are derived from SPV Panel Power. In case the SPV Panel Power is not sufficient to cater to ONT Load and Battery Charging , Mains AC I/P delivers the output

Solar Panel & CCU Connectivity

Fig. 3.5.17 Solar Panel

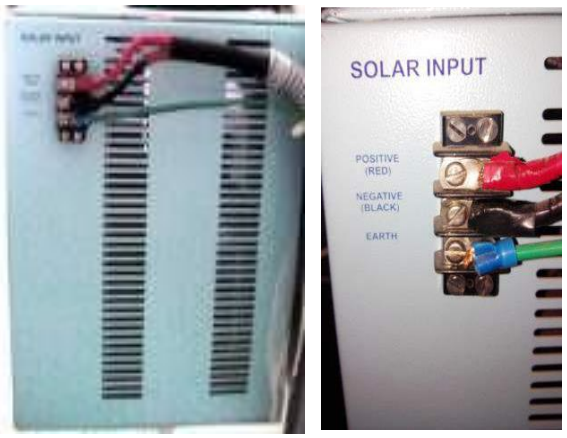


Fig. 3.5.18 Solar Panel CCU Connectivity

GPON Physical

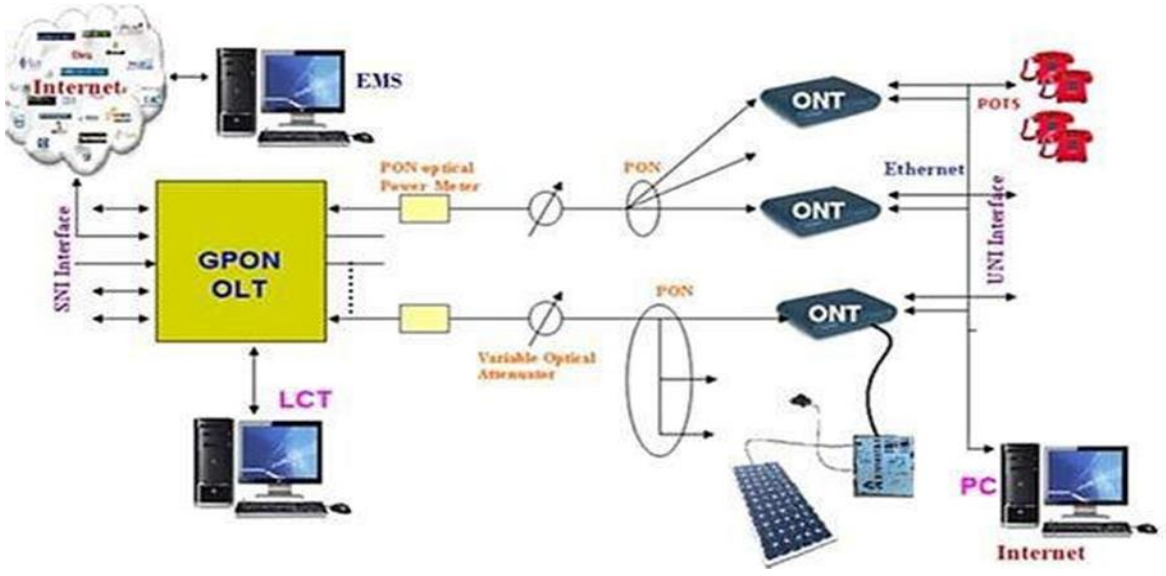


Fig. 3.5.19 Physical Conncetivity of GPON System

Physical installation is followed up by site survey and the input received from planning entity. refer Fig 6.2.8

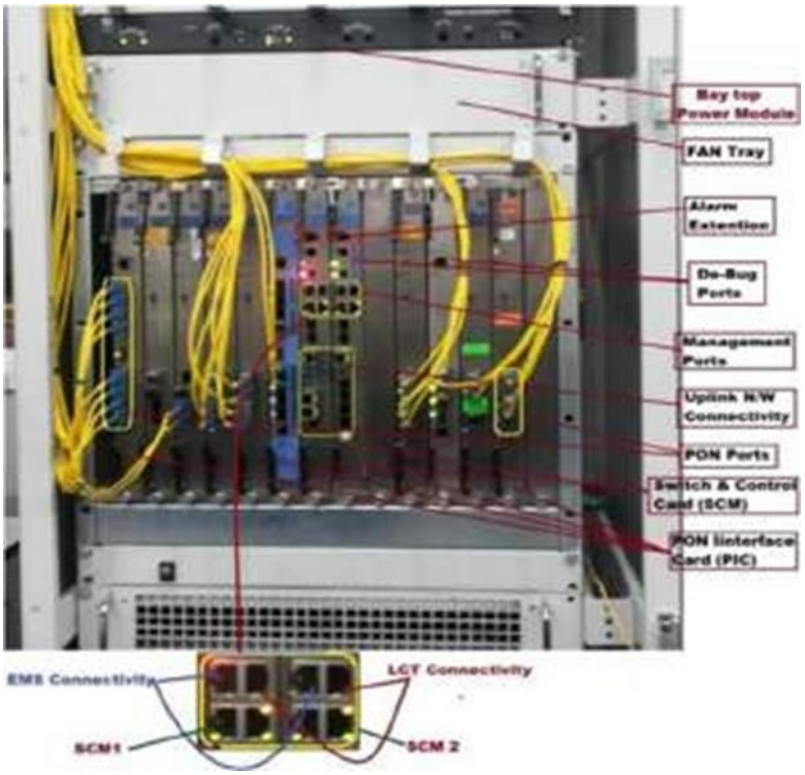


Fig. 3.5.20 OLT Connectivity at block level

Fig. 3.5.21 ONT Connectivity at Gram Panchayat (GP) level

Infrastructure Check list at OLT location:

Test description	Observations	Remarks
Layout drawing	As per engineering drawing document (EDD)	OK / Not OK
Check of Earthing (in Ohms)	Measured Value:	If earthing is available then earth measurement is to be done. If not feasible, a certificate from planning along with last reading (within six months) to be taken.
Check of Air conditioning (if available at OLT location)	Available / Not available	If existing, required temperature and humidity conditions are to be ensured as per node requirement.
Check of Documentation	Available / Not available	Technical Manuals in CD
Check of Power plant/Battery including inverter.	Available / Not available	
*Engine Alternator	Available in working condition / Non- working Condition / Not available	
Check of Firefighting Equipment /Fire Detection system	Available / Not available	
Sign. Writing on the equipment	Done / Pending	
Network diagram in the form of OLT port diagram.(To be arranged by BBNL PMUs)	Available / Not available	

The OLT Installation Engineer will perform above site verification before installation. He/ she will have the following data for the installation reference

OLT Equipment Details:

Sl.No	Details
1	OLT Location
2	Block & Dist. Name
3	OLT Location ID/IP address
4	OLT Model No
5	OLT Sl. No.
6	OLT Capacity (4/8/16 Port)
7	QA Reference

Software Details

Sl.No	Description	S/W Ver
1	GPON OLT	
	a) SCM	GPON_COM_2.17
	b) PIC-4	GPON PIC 2.33
2	ONT (UTL-ONT-72)	GPN OTB L4 1 7
3	EMS	V3.6.3
4	LCT	2.17

OLT Installation Engineer configure parameters as below (Receive the details from service provider).

Sl.No	Item
1	OLT Management IP (in Band)
2	OLT Management Gateway (In Band)
3	OLT Management IP (Out of Band)
4	LCT/EMS Server IP (In Band)
5	LCT/EMS Server Gateway
6	OLT MGMT VLAN
7	High Speed Internet VLAN/s
8	VoIP Outbound Proxy Server
9	VoIP VLAN
10	User 1 & telephone number
11	Password
12	User 2 & Telephone Number
13	Password
14	DHCP Server IP address

Some of the Test conducted before commissioning

Test id	Test description
Test -001	Physical Verification of the Equipment at OLT site
Test -002	Verification of Power supply requirement of OLT
Test -003	Verification of Power supply redundancy at OLT
Test -004	Verification of Hot Swapping functionality of OLT

Test -005	Verification of Optical Power Measurement of OLT Uplink Ports
Test -006	Verification of Optical Power Measurement of OLT GPON Ports
Test -007	Verification of Service Restoration on OLT Reboot
Test -008	Verification of LOS on PON port due to fiber cut between OLT & 1st Splitter
Test -009	Verification of OLT Switch Card (SCM) /uplink Redundancy at OLT
Test -010	Verification of Earth Connectivity
Test -011	Verification of mechanical specifications
Test -012	ONT Node Tests with OLT

ONT Installation

- ONT installation engineer follow the below steps
- Site Survey
- Installation
- Electrical Wiring
- Site Security, Hygiene
- Earthing
- Grounding

ONT Site Survey

Site survey form inform the engineer referring Village panchayat, Block/taluk, District, State, & Tools/Materials Required.

Tools and material for Site survey

- Measuring tape
- Compass
- Book/Pen/Pencil
- Chalk piece/marker pen

Building is facing..... Direction

Surroundings..... Dense/open field/any other information

General power availability any known pattern of power unavailable hours.

Upload front elevation picture.

Roof Survey

- Access to roof stairs or ladder
- How many floors
- Selected place for SPV and Mark it. Upload picture d. Any shade on roof
- Hardness of roof (suitable for drilling 3inches (12.5mm dia) holes f. Identify Route for DC/earth cable from Solar panel
- Is the route straight in to ONT room

Earthing Pit

- Near to DC cable entry point to the ONT room. At least 1mtr from foundation and no obstruction within a 2 meter-radius.
- Type of Soil soft/hard/rocky
- Mark earth location
- Upload a picture

ONT ROOM

- Place for Splitter on wall should be near to BBNL FDF and computer table (about 1.5 meters from floor level).
- CCU location near to ONT and near to AC power point. You need to tell VGP that exclusive earth point is required for CCU
- CCU location should be such that DC cable length is a maximum of 10 to 12 meters from solar panel.
- Wall around CCU should be clear, it can be wall mount also.
- ESTIMATED DC cable length, Earth cable length from CCU to earth pit and FO length from Splitter to ONT

Contact Details to Collect:

- Head of Panchayat appointed by State govt
- Computer operator
- If possible Peons Contact number
- Name of Panchayat
- Distance from OLT location
- Nearest District and distance from State capital
- How is the transport facility like public/private

ONT Installation Procedure:

- Location/space Identification of equipment installation.
- In between CCU to SPV the standardize cable length is 12m only. More than that voltage loss will come. So try to install the SPV below 12m cable length.
- Fix Splitter near to BBNL termination box, if its already fixed in GP.
- Splitter of 1:4 or 1:8 installed based on planning.
- Then ONT and CCU should be wall mounted as per site condition. Use nails for fixing ONT's at wall instead of screws.
- Route SC/PC to SC/APC (one end blue and other green) optical patch cord splitter to BBNL termination. Blue end should come at BBNL termination box side.
- Route SC/APC to SC/APC (both end green) optical patch cord splitter to ONT.
- Connect all connectors and switch on all equipment. Connect CCU unit to power if it is available in site. It should connect power main instead of UPS power.
- Optical patch cord also need to be connected before leaving the site, in BBNL termination box it should be connect 1st port. In the BBNL termination box, there are 4 connectors: the 1st one is blue, the 2nd is orange, the 3rd is brown, and the 4th is green. Sometimes, it has misaligned, so you have to identify them by color code. BSNL will terminate either 1st or 2nd port. Most of the site 1st port only they used.
- Note all serial numbers in installation form and get it sign from GP official. Also collect SPV document which is coming with SPV box.

Note: Optical patch cord should be put inside the flexible conduit and need to do it carefully. It should not bend while handling.

Fig. 3.5.22 ONT Connectivity with Splitter and CCU- Wall Mount 1

Fig. 3.5.22 ONT Connectivity with Splitter and CCU - Wall mount 2

Earth cable from SPV stand and the CCU unit will be routed to earth pit/earth rod terminal using 4sq mm green multi-strand wire. Part of conduit which is exposed on ground needs to be buried. All Flexible conduits inside building, while taking bend should take smooth curve. If sharp it will become V shaped after some time.

Fig. 3.5.23. Earthing

GPON Test conducted at ONT:

Test id	Test description
Test -012	ONT Node Tests with OLT
Test -013	Physical Verification of the ONT site
Test -014	Verification of Power supply requirement of ONT
Test -015	Verification of LOSi on Fiber Cut for an individual ONT:
Test -016	Verification of LOSi on Fiber Cut & DGi on Power off for the last working ONT on the PON
Test -017	Verification of Receiver sensitivity at -27dBm
Test -018	Verification of High Speed Internet Service & Wi-Fi
Test -019	Verification of DS/US & Bandwidth Assignment
Test -020	Verification of VoIP Service within OLT

Test -021	Verification of Incoming call to ONT
Test -022	Verification of Outgoing call from ONT
Test -023	Verification of Service Restoration on ONT Reboot
Test -024	Testing and Verification ONT Earthing
Test -025	Verification of RFC 2544 (QoS check for throughput, latency and frame loss)

GPON Test conducted at SPV:

Test id	Test description
SPV-Test-01	Physical Verification of SPV, CCU with Battery
SPV-Test-02	Verification of charging from solar panel
SPV-Test-03	Verification of charging from A.C MAINS
SPV-Test-04	Verification of AC Power Supply & SPV Output FAIL
SPV-Test-05	Verification of SOLAR PANEL
SPV-Test-06	Battery Health check test
SPV-Test-07	Verification of FUSE

GPON Test conducted for Splitter:

Physical Verification & Insertion Loss Measurements of the Optical Splitter Purpose	**Physical Verification of the splitter at ONT site. & measurement of insertion loss.**
Procedure	Physically verify the type of splitter installed. ONTs connected to the splitter may be recorded. Calculate the Insertion loss of the splitter as per the procedure explained above.
Expected results	1. Insertion Loss of 1:4 splitter : < or = 7.1 dB 2. Insertion Loss of 1:8 splitter: ,< or = 10.5 dB

OLT to DCN and EMS

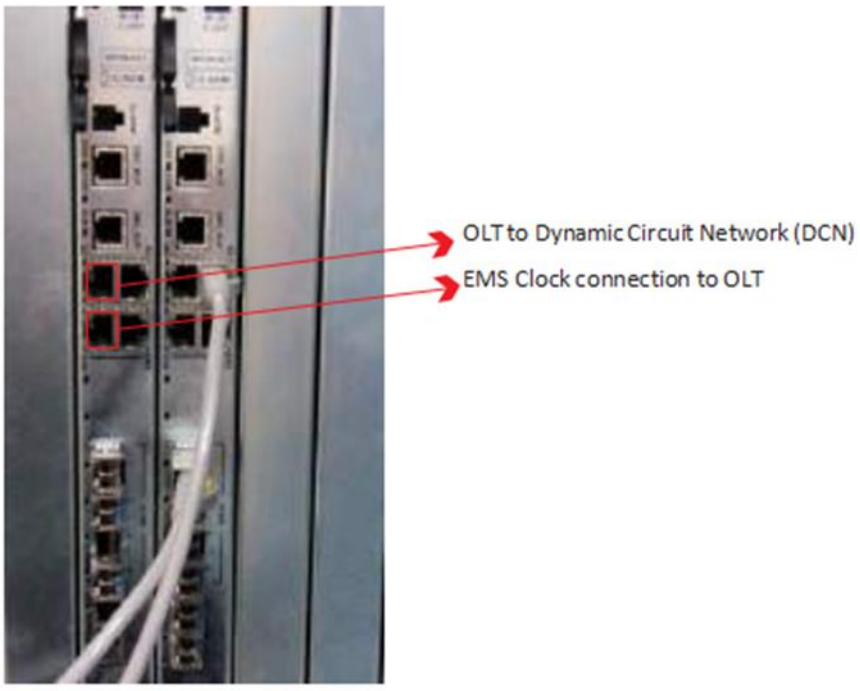


Fig. 3.5.24. OLT to DCN and EMS

NMS:

Network Management System will monitor the entire system on bird view and notify the issue in remote-to-remote considerations.

NOFN NMS provide information on:

1. EMS status
2. OLT Status
3. ONT status
   - Using NMS : OLT and ONT Type report could be generated and analysed on the issues if any.
   - NMS shows whether ONT & OLT are active or not.
   - NMS Have Features to restart and Reset Both ONT & OLT.
   - NMS Could Update the OLT Via EMS. ONT s MAC and serial number will be observed carefully at NMS and incase of any replacement of ONT have to updated To NMS Engineers.
   - NMS Classifies the Operations into Zonal level, state level, district level and Block level.
   - NMS could be used to manage OLT – PIC and SCM cards
     - **NMS have feature of Trouble Ticket handling.** NMS engineer monitor and take relevant actions and l close the ticket once the issue get rectified. Power failure and power fluctuation auto restart will create tickets at NMS and get auto cleared as soon the system comes back to system.
     - **Manual Ticket Creation and solvation :** Issues and concerned raised from the field could also be manually counted and trouble ticket could be raised.
     - **NMS - Fiber Management System:** Fiber connectivity is one of the critical parameter in the GPON system and hence the end to end fiber connectivity is tested and evaluated.

To assure the link effectiveness and consistency the fiber system is monitored by NMS in terms of:

- Zone
- State
- District
- Block
- BNL- block location
- Panchayats
- GPL- Gram Panchayats

Any device discontinuity or not reachability, fiber cuts could be tested by checking in nodal elements as listed above. To ease the process, the connections are named under segments and originating and terminating fiber is listed and named.

At NMS Segment ID used to monitor the end device connected length of the cable effectiveness, capacity and status of the segment. In NMS Fiber connection end to end could be monitored. Any error or issue at the fiber system create Alarms at NMS and there by the NMS will trigger the solvation.

EMS

EMS system is OAM which maintain and monitor the activities on OLT and ONT. EMS displays basic information of switch control board. Users could modify the networking configurations. Major networking configurations include IP address, network mask and gateway, etc. Before configuring VLAN, administrator should be maintain and verify the status of protocol pool base.

Port-Protocol -VLAN Trunk can be verified only in the protocol pool. Business circulation will be started only after the authorization procedures finished. All the ONUs which are connected with PON interfaces will be authorised except those are belonging in illegal ONU list. Optical Network Unit authorization is carried out through database of black and white ONU list. By means of MAC address ONU will be authorized by the switch control board legally. Illegal ONUs are the devices which its MAC address will be listed in black list ,while those MAC address listed in white list are called legal ONU.

Ethernet and GPON Design

GPON can support Triple–play services. There is a bandwidth scarcity in access network where they are using twisted pair cables. GPON provides high- bandwidth for transmission, so high data rate. So we are using GPON to achieve High bandwidth requirements for services like live TV broadcasts and IPTV. So GPON will support much more coverage (up to 20 km) to provide service in maximum geographic area and to overcome limitations of twisted pair cables in access network and also avoid number intermediate network nodes. The latest available standards says that, GPON supports integrated services in a good way. GPON is the choice of large carriers in the international market.

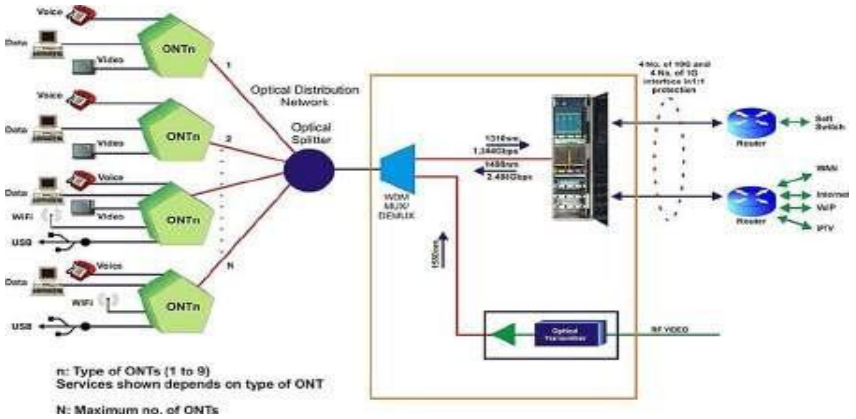


Fig. 3.5.25. ONT- GPON Design Architecture

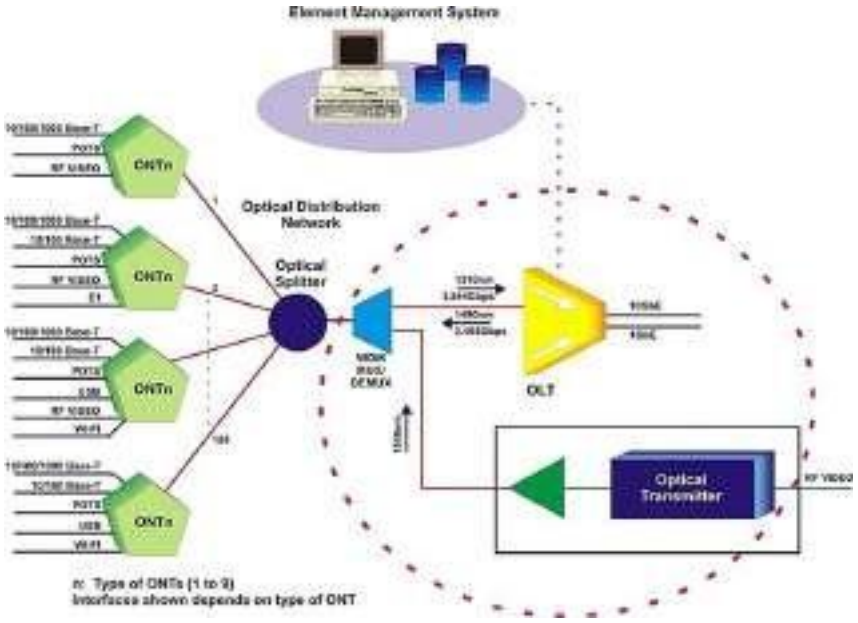


Fig. 3.5.26. ONT - GPON Design Architecture

Optical Power measurement of OLT

In OLT, ONT is identified by the MAC ID connected to the PON and activated by LCT .the services @ ONT must be defined and configured in OLT.

IN GPON OLT- the connected SFP optical Parameter values should be in the following range

1. RX Power: -8 to -27 dBm
2. TX Power: -1.0 to +5 dBm

RX and TX value differs for varying SFP, few expected results are as follows:

1. For 850 nm (1G SFP) the optical Parameter values should be in the following range
   a. RX Power (Min to Max): -17 to -3dBm
   b. TX Power (Min to Max): -9.5 to -4.5 dBm
2. For 1310 nm (1G SFP) the optical Parameter values should be in the following range
   a. RX Power (Min to Max): -18 to - 3 dBm
   b. TX Power(Min to Max): -9.5 to -3 dBm
3. For 1550 nm (1G SFP) the optical Parameter values should be in the following range
   a. RX Power (Min to Max): -18 to - 3 dBm
   b. TX Power(Min to Max): -9 to -3 dBm

ONT- tested for end-to-end connection

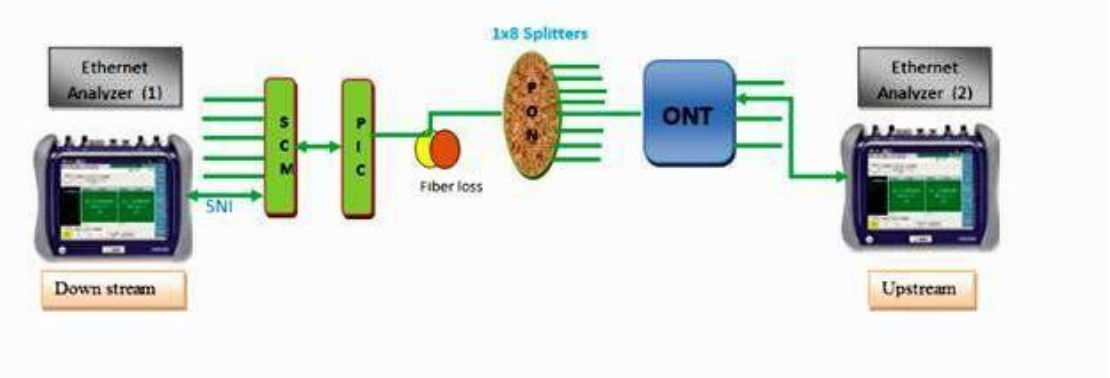


Fig. 3.5.27. ONT- Test for End-to-end Connection

As shown in the figure above, Ethernet analyzer is connected to SCM card at OLT and to ONT port at GP location. Verify the connectivity ad status by LCT and vary the transmit rate and verify the end to connection and its stability.

OLT engineer receives group of IP 's and VLAN Id's from the planning team for commissioning. Every OLT will take several IP's and ONT is represented by its MAC ID looped with VLAN Id's. Below shown the snap shots assigning OLT IP and OLT VLAN Id using LCT at OLT block level.

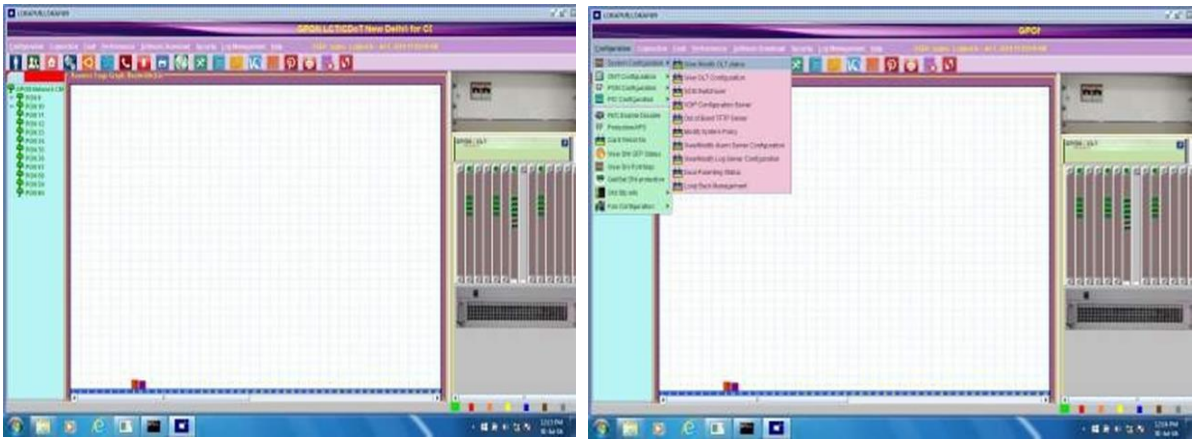


Fig. 3.5.28. EMS LCT Snapshot

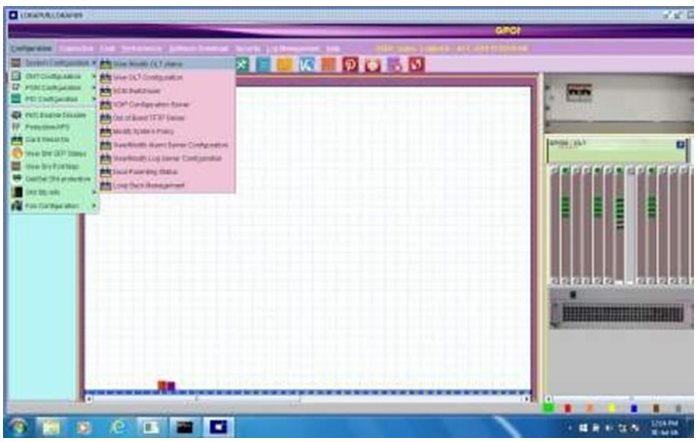


Fig. 3.5.29. View / Modified OLT Status Snapshot

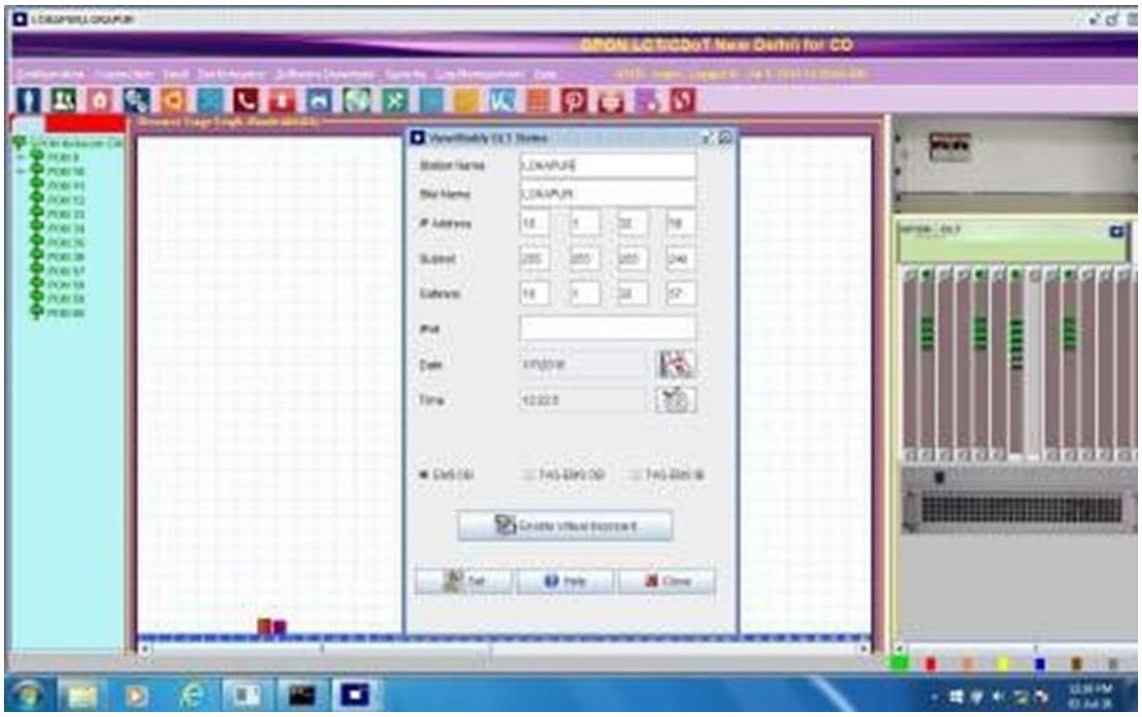


Fig. 3.5.30. Assign IP address Snapshot

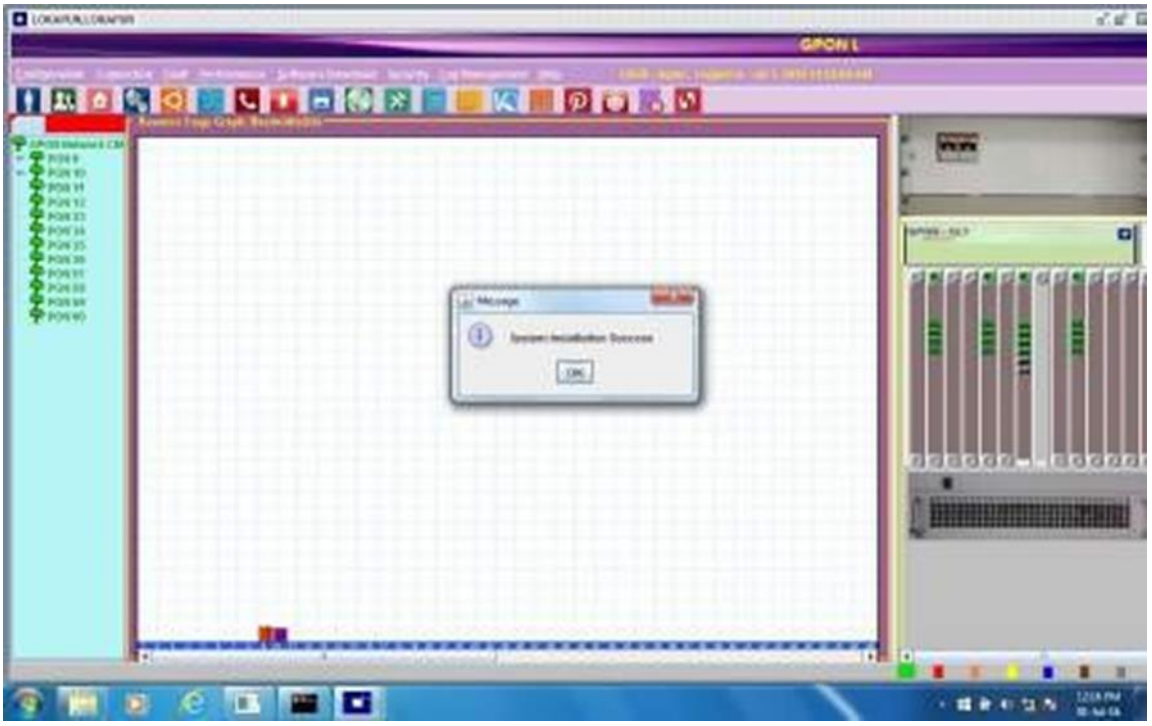


Fig. 3.5.31. System Installation success Snapshot

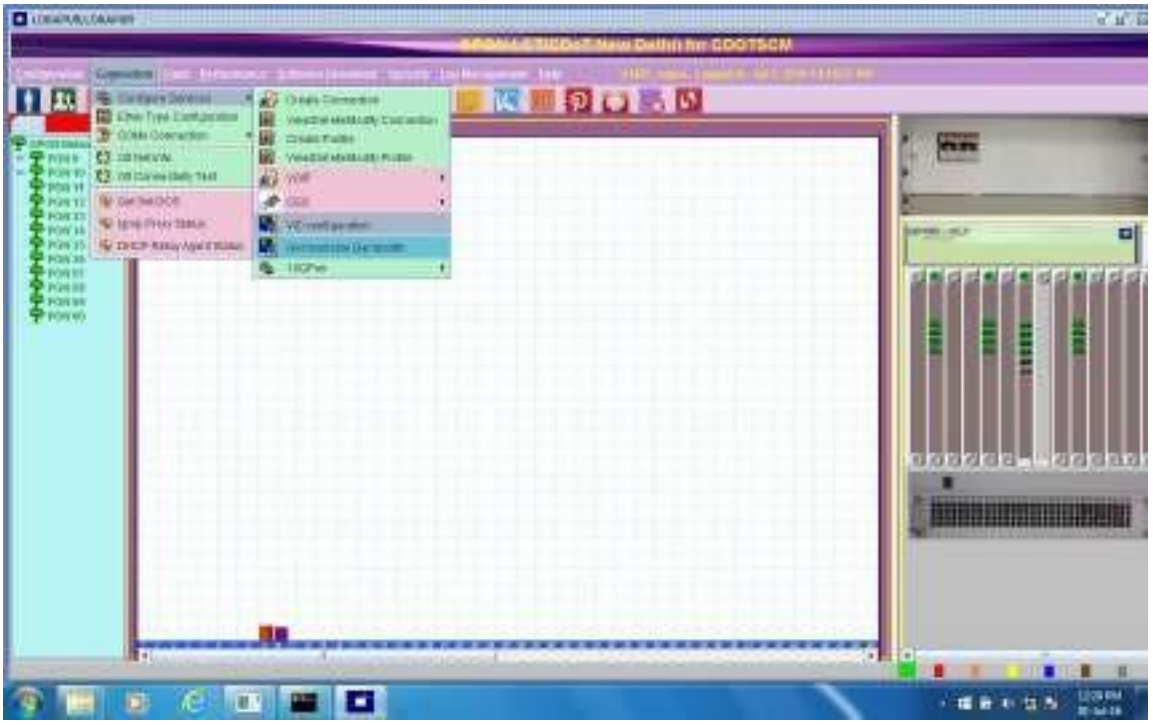


Fig. 3.5.32 Under connection tab Enter VID Configuration - Snapshot

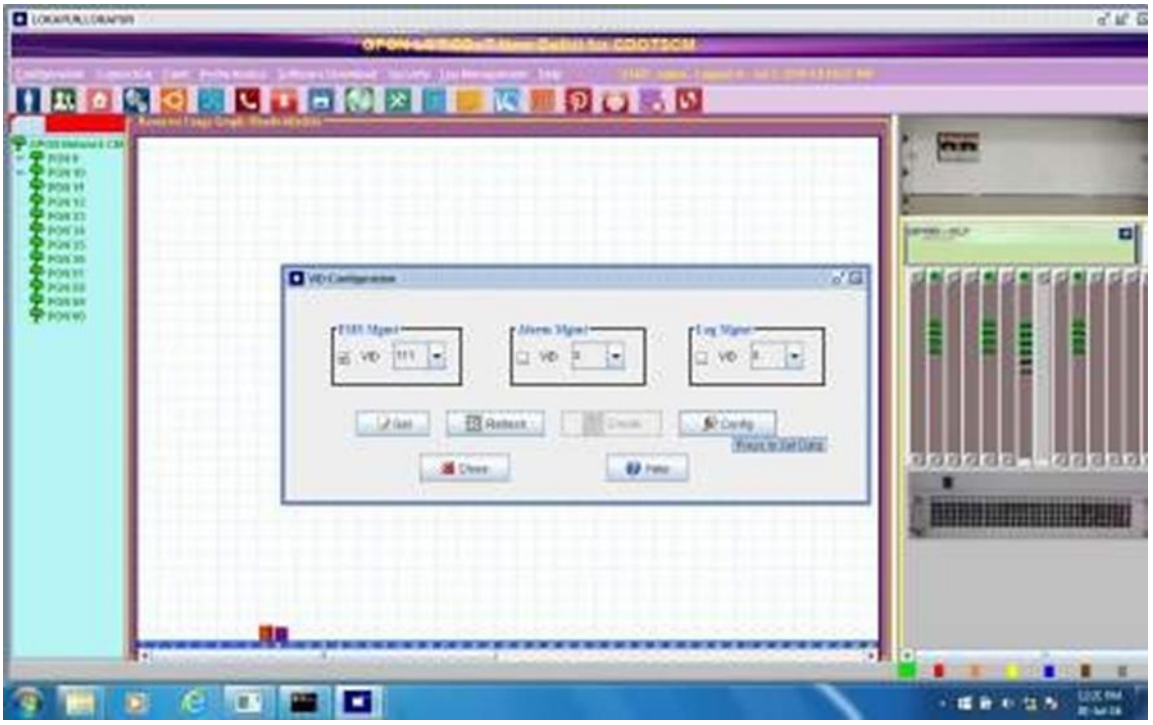


Fig. 3.5.33. Verify / Edit VID - Snapshot

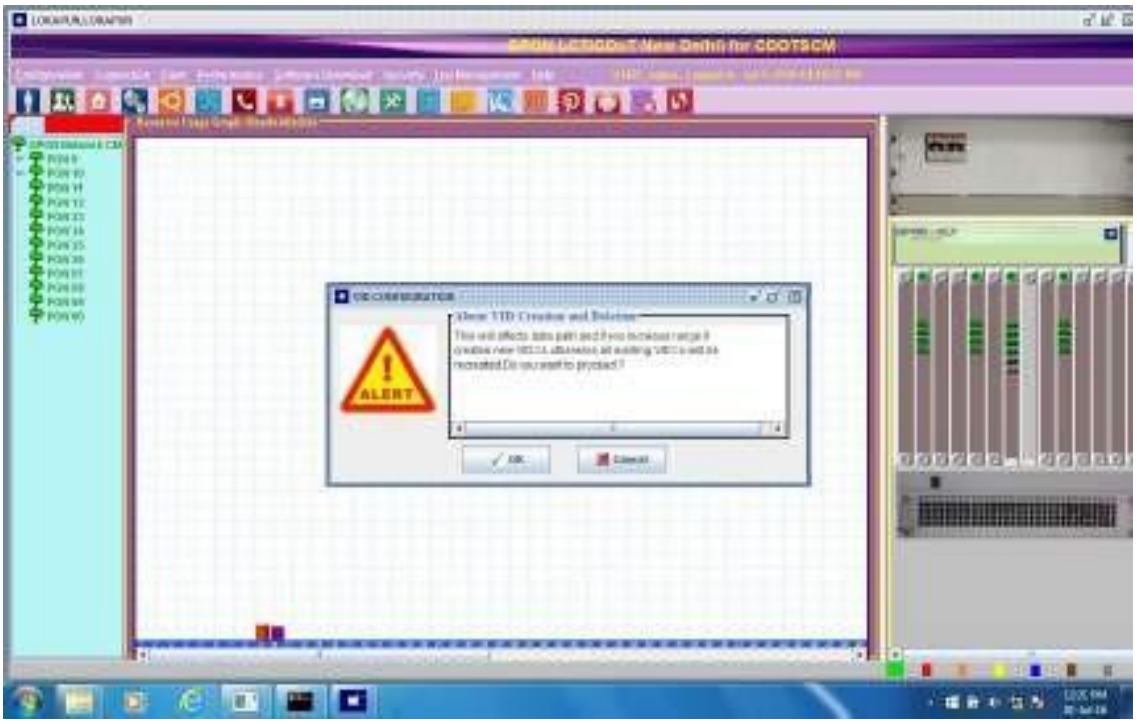


Fig. 3.5.34 Click Ok to Proceed with VID Configuration - Snapshot

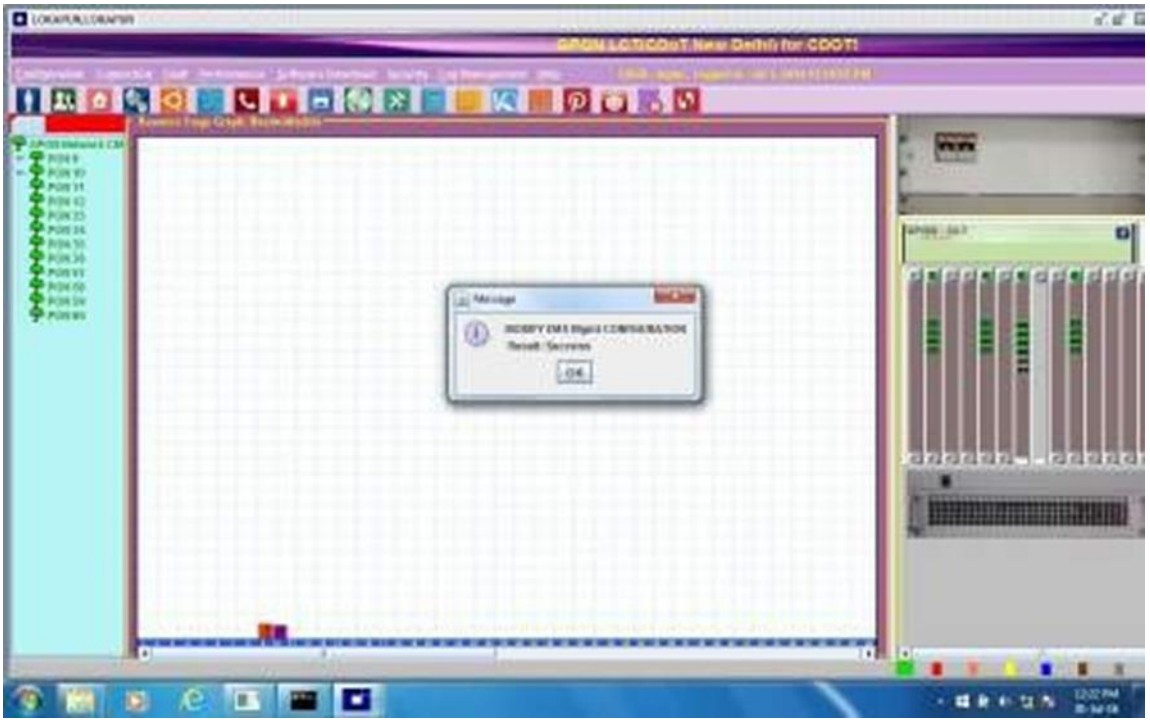


Fig. 3.5.35. VID Modification Success - Snapshot

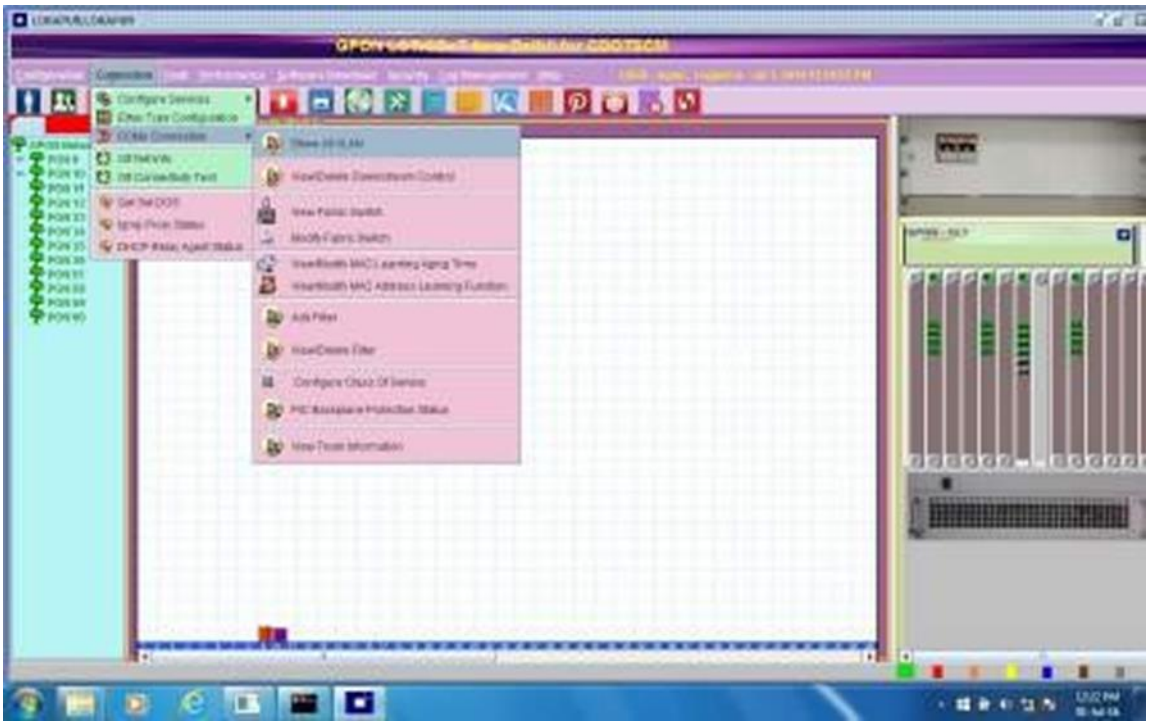


Fig. 3.5.36. Verify VID assigned by entering show all VLAN Tab under COM e connection - Snapshot

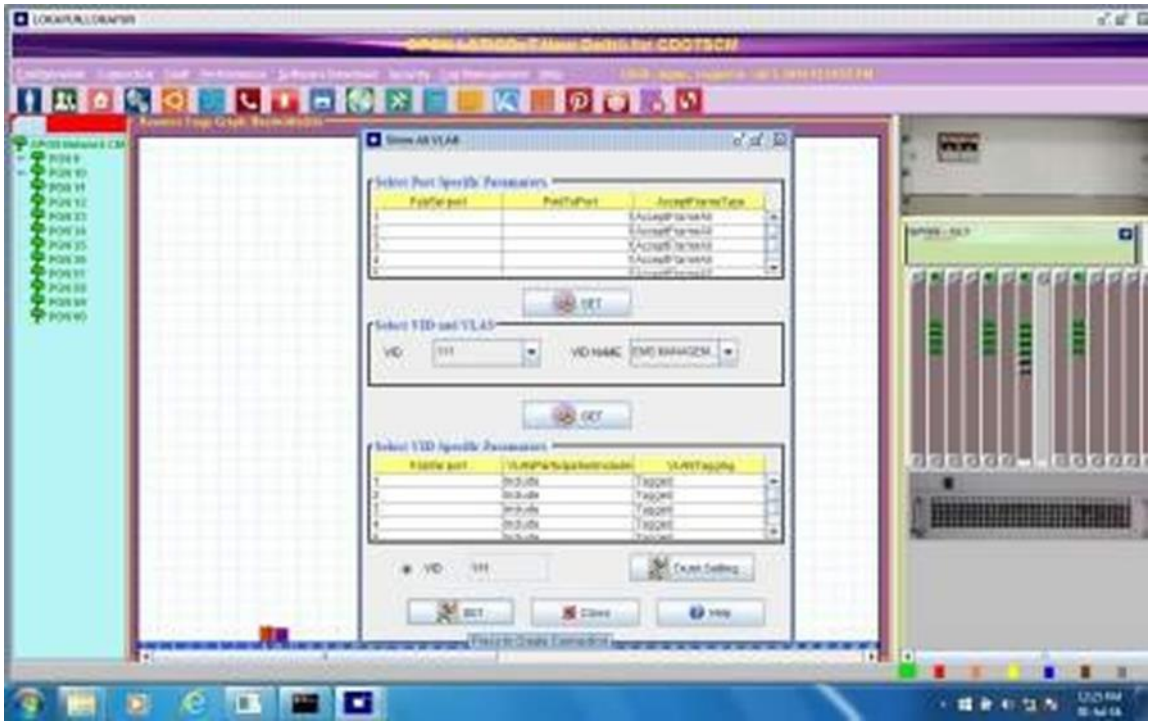


Fig. 3.5.37. Confirm the VID Name and Number and Press Set for Successful entry - Snapshot

GPON Service (Internet) Connectivity Diagram

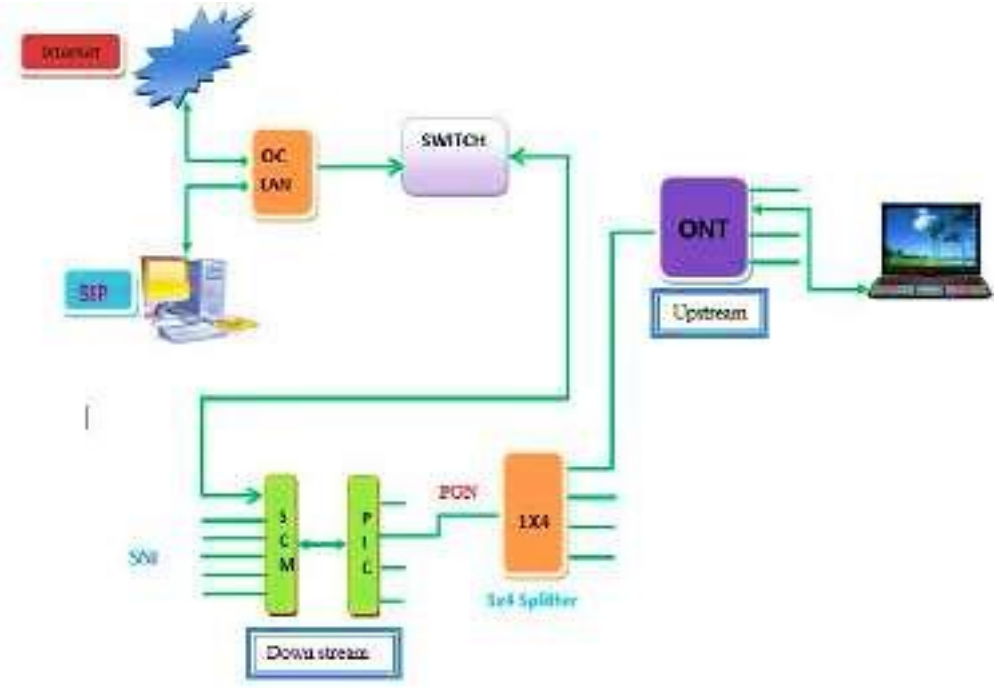


Fig. 3.5.38. GPON - Internet Connectivity Diagram

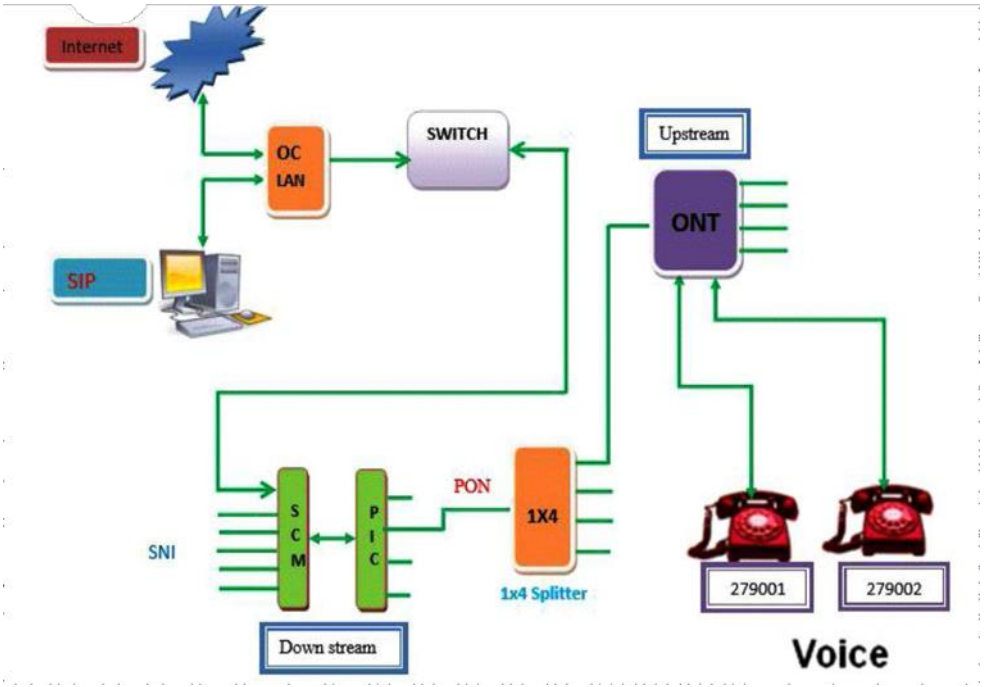


Fig. 3.5.39. GPON - VoIP Connection Diagram

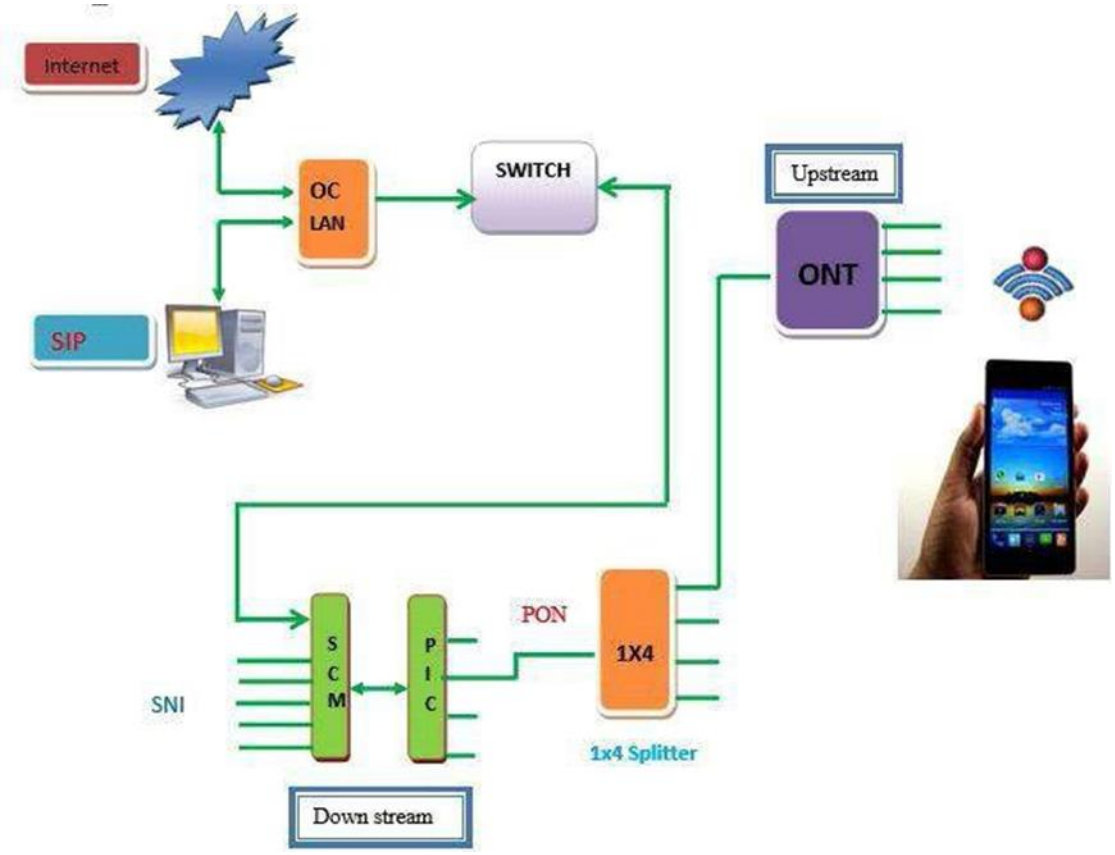


Fig. 3.5.40. GPON - Wi-Fi Connection Diagram

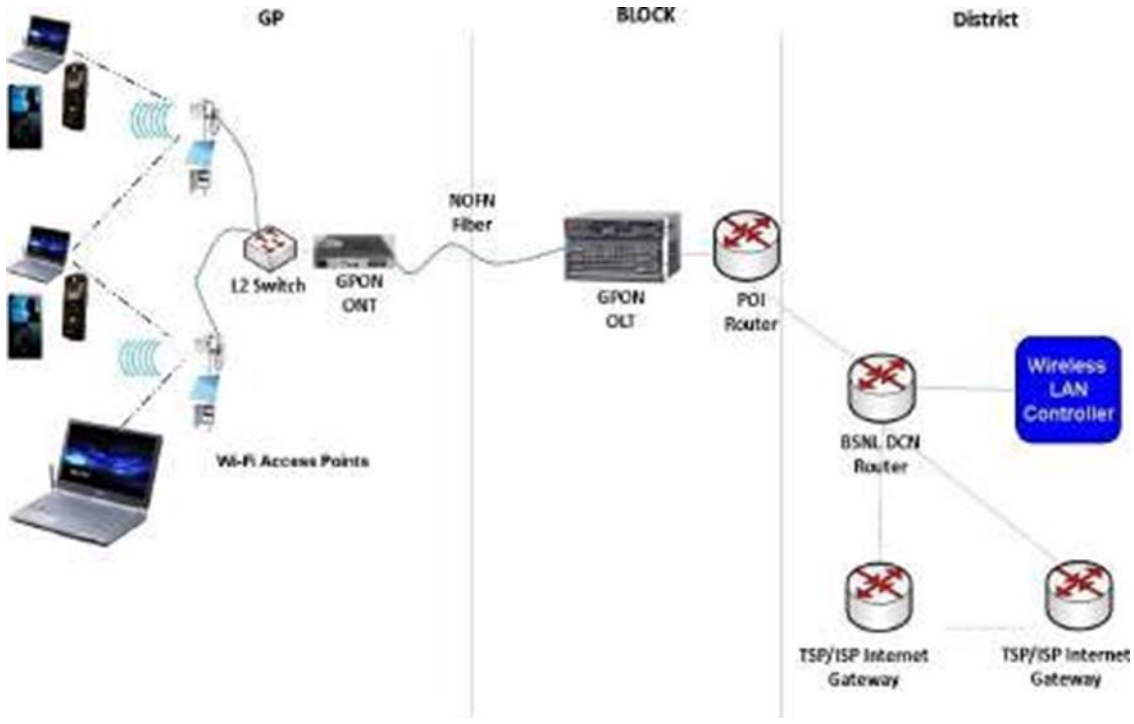


Fig. 3.5.41. Wi-Fi Network Connected To NOFN GPON Network

Notes

UNIT 3.6: Global Positioning System (GPS)

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the Global Positioning System (GPS) and its working principles.
2. Describe the utility and applications of Global Positioning System (GPS) in various sectors.

3.6.1 Global Position System (GPS)

The Global Positioning System (GPS) is a space-based navigation system. GPS provides time information and location /Position on or near earth in any environmental conditions. There should be an unobstructed line of sight to at least four GPS satellites. GPS is utilizing from around the world for various applications and services, gives critical capabilities to military, civil, and commercial users.

For utilizing its service, pre-requirements are a GPS receiver, compass altimeter and good or basic navigation skills!

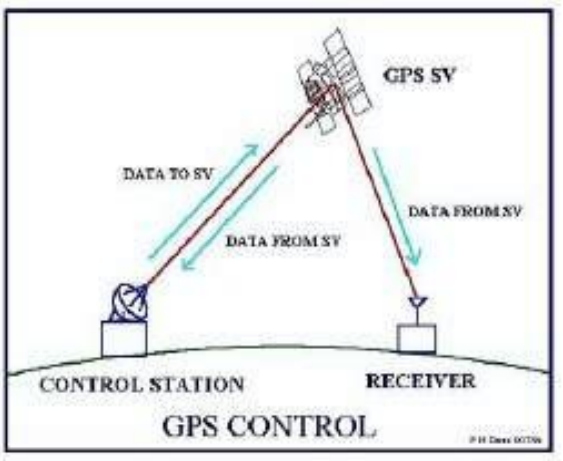


Fig. 3.6.1. GPS Control

Parts of a GPS System

The GPS is working based on time and the known position of special satellites. Satellites have stable and synchronized atomic clock which provides the accuracy. They will correct any drift happened from the true time on the ground daily. So, the satellite locations are known with great precision. Even GPS receivers have clocks as well, but they are not synchronized with true time, and so they are less stable. GPS satellites transmit their current time and position continuously. Also a GPS receiver monitors multiple satellites and solves equations to find the precise position of the receiver and its deviation from true/ original time. So a minimum of four satellites must be in synch of the receiver for it to calculate four unknown quantities (three position coordinates and clock deviation from satellite time).

GPS Receiver- features are:

1. 10+ meter accuracy
2. Computer cable
   - Download and upload maps, routes and way point.
   - Upgrade over the internet

Computer Mapping Software

- Can map out tracks and way points
- Can plan and upload routes, tracks and way points

Fig 3.6.2. GPS Receiver Control

Receivers may also have

- Digital compasses
- Barometric Altimeters
- FRS Radio
- Other features.

Satellite positions (geometry)

- Weather
- Multipath
- Timing errors
- Typical error is 10+ meters.

All GPS are 12 channel: can receive up to 12 satellites. Some of the newer satellites & receivers can receive through thinner solid objects like cars, building walls and forest canopy. Terrain and larger buildings are still too big.

Receivers Record

Track Logs

- Collected any time receiver is on.
- Should be cleared before each mission
- Overwrites previous positions, if track memory is full

Tracks

- Track logs can be saved for reuse
- Not as much detail as log
- Can be drawn on computer map and uploaded

Waypoints : Stored or entered locations

Routes: Set series of way points & Less detail than a track

Navigation

1. Need to have stored way points.
2. Travel is in a straight line from way point to way point (route). Can also be a track you uploaded and follow.
3. Feedback is distance and direction compass and pace may be more efficient.
4. Can use to check progress and whether you are still on track.
5. Can save way points along the way and follow back (reverse route).
6. Straight line may not be safest - use a map when planning or to double check!

Fig 3.6.3. GPS Navigation waypoints

GPS Navigation Strategies

1. Receiver downloads new position every 5 to 30 seconds.
2. "Compass" may jump
3. Best to follow hand compass or electronic compass rather than GPS compass.
4. If receiver has electronic compass, set it so it will kick in at under 2 mph.
5. As long as distance is decreasing, you are going the right direction.
6. Can select easier terrain to increase travel speed.

Use Basic Navigation Techniques!

Better: Follow road (or handrail it) until distance starts to increase. Now follow GPS the shorter distance into the target. If curve is easy to identify, can use GPS to navigate road to this checkpoint and then use compass and pace into target from here.

Garmin Basics

1. There are differences between models as well as between brands.
2. Basics are the same.
3. Should sit down with instruction booklet and learn all the functions.

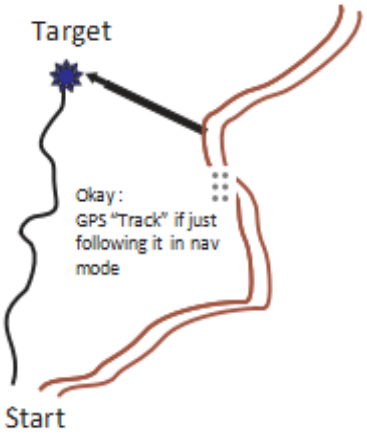


Fig. 3.6.4. GPS Track targets

- Shows map of current location.
- If navigating, some will show purple line to follow.
- Can zoom and pan on in some models.

Fig. 3.6.5. GPS Devices

Main menu

- Most functions found here
- Setup
- Waypoints - Create, Edit, Delete
- Tracks - Setup, Clear, Save, Turn on and off.
- Calibration
- Other

Fig. 3.6.6. GPS Main Menu

System: Basic look and feel, turn WAAS on and off. Set compass to kick in when speed = 2mph.

Display: Set backlight.

Set backlight to stay on.

Set for lowest level to do night work.

Units: Coordinate system, Datum, Units for distance and elevation, etc. Waypoints on most Garmins, hold enter key to mark a waypoint or go to main Menu to mark. Can then edit Name, Symbol, Location. Have a naming convention so way-points show up in the list together. Group important points with the same symbol. like a folder can bulk delete everything with the same symbol and not others. Select named waypoint, then GOTO to start navigation.

Fig. 3.6.7. GPS Elévation

Fig. 3.6.8 Way points - Marking

Fig. 3.6.9 Way points - Editing

Navigation:

1. Main Menu - waypoints or Find
2. Select desired waypoint
3. Go To
4. Map Screen or compass screen comes up

Fig. 3.6.10. Way points - Find

GPS Navigation

Navigation is a process of monitoring and controlling the movement of a vehicle or object from one location to another. There are generally four navigation categories that are land navigation, marine navigation, aeronautic navigation and space navigation.

- Once map or compass screen comes up:
- Start walking
- You must be moving for navigation mode to work.
- Turn so compass points to top of unit or the arrow points down the map track.
- When you get close
- Switch to coordinate screen to find final coordinates.
- GPS usually has a 5-to-10-meter error, more in poor conditions.
- Mark where the GPS takes you and search a 10 meter full circle around the point.

Fig 3.6.11. Navigation Direction

Calibrate:

Calibration is the process of finding out a relationship between any two measures that are unknown (when the measurable quantities are not given a particular value for the amount considered or found a standard for the quantity). When one of quantity is known, which is made or set with one measuring device, estimation is made as comparative way as conceivable with the calibrating device utilizing a second device. The quantifiable measure may vary in two devices which are proportional. The device with the known or doled out rightness is known as the standard. The second device is the unit under test, test instrument, or any of a few different names for the device being adjusted.

- Only if your GPS has an altimeter and/or compass.
- Calibrate will not show in menu, if you do not have it.
- Calibrate, altimeter, known elevation.
- Must be at that actual elevation to calibrate.
- Should re-calibrate daily or when weather has changed.
- Calibrate, compass
- Hold GPS level and slowly turn 2 rotations receiver will tell you when it is complete.
- Must re-calibrate after changing datum and coordinates.
- Navigation will not work right if compass not calibrated.

Fig. 3.6.12. GPS Calibration

Notes

UNIT 3.7: PON Maintenance & ONT - CCU Indicators

Unit Objectives

By the end of this unit, the participants will be able to:

1. Apply standard procedures for PON network maintenance and troubleshooting.
2. Identify the key hardware features and interfaces of an Optical Network Terminal (ONT).
3. Interpret the LED indicators on a Charge Controller Unit (CCU) for status monitoring.

3.7.1 PON Maintenance & Troubleshooting

Troubleshooting a Passive Optical Network (PON) is a critical skill for network technicians. Due to the point-to-multipoint topology, a single fault can affect a large number of subscribers. Effective maintenance relies on quickly identifying the location and type of fault.

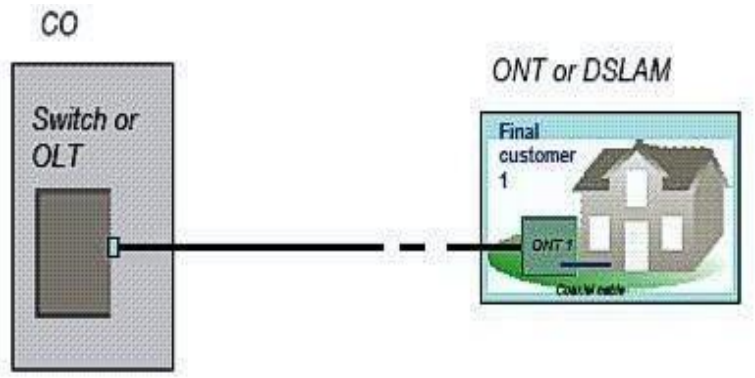


Fig. 3.7.1. FTTx Study Case=Point to Point FTTH Network

Troubleshooting a PON Network

PONs are defined by standards from bodies like the International Telecommunications Union (ITU-T) (G.982, G.983, and G.984) and the Institute of Electrical and Electronic Engineers (IEEE) (802.3ah, 802.3av). A typical PON consists of a single Optical Line Terminal (OLT) interface connected to a splitter, which in turn connects to multiple Optical Network Terminals (ONTs) at customer premises.

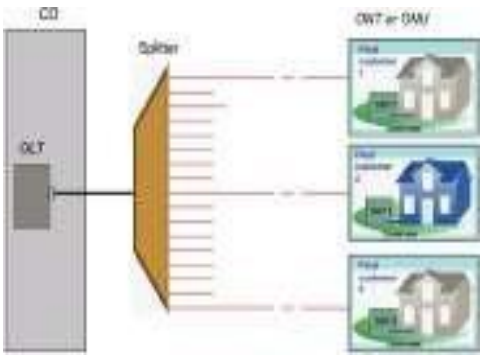


Fig 3.7.2. Simple PON Network Topology

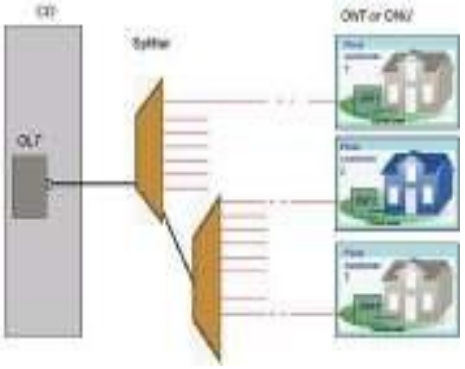


Fig. 3.7.3. Cascaded PON Topology

Operators can use the Network Operations Center (NOC) and management systems (OAM) to identify affected customers and pinpoint the general location of a fault.

Common Troubleshooting Scenarios:

Case 1: Only One Customer Affected

- This is the simplest case. A single customer's service is down, while all others on the same splitter are working.
- Probable Fault Locations:
- The fiber drop from the splitter to the customer's home.
- A fault with the ONT equipment itself.
- The customer's internal home wiring.

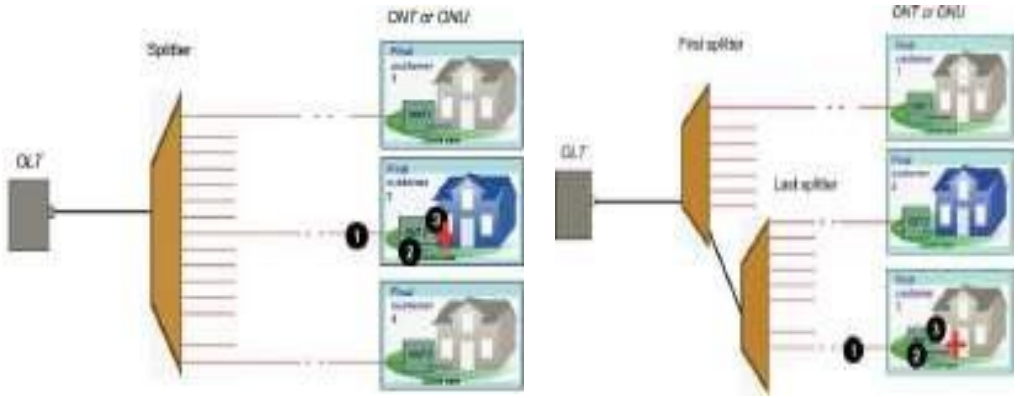


Fig. 3.7.4. PON Case 1 - Possible Faults When only one Subscriber is affected

Case 2: All Customers on One Splitter Affected (in a Cascaded PON)

- In a cascaded network, one splitter's users are all down, while users on other splitters connected to the same OLT are unaffected.
- Probable Fault Locations:
- The splitter itself has failed.
- The fiber link between the two cascaded splitters is broken

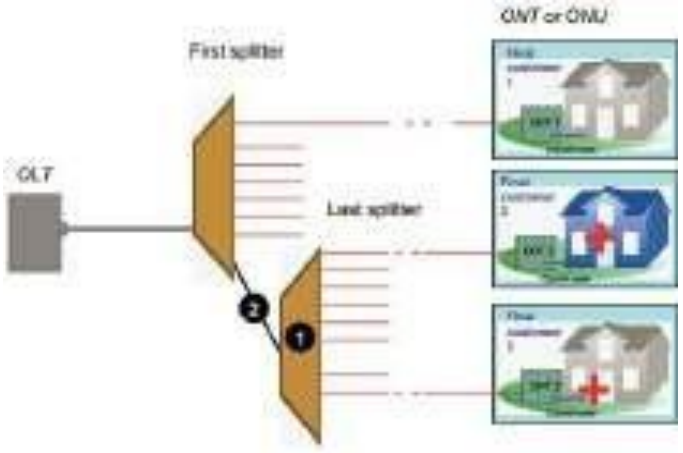


Fig. 3.7.5. PON Case 2 - Cascaded PON without getting service from last splitter

Case 3: All Customers on the Entire PON Affected (at the OLT Level)

If all customers connected to a specific OLT interface are without service, the issue is at the highest level of the PON.

Probable Fault Locations:

- The feeder fiber cable connecting the OLT to the first splitter is cut.
- The OLT-side splitter has failed.
- The OLT equipment itself has failed.

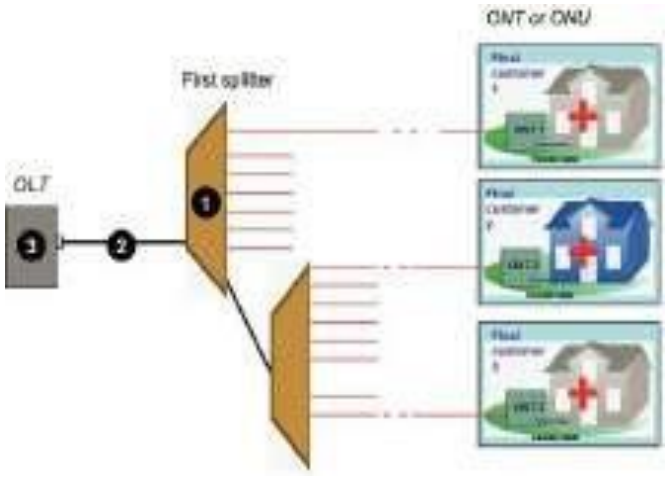


Fig. 3.7.6. PON Case 3 - All Subscribers are affected (All Connected to the first Splitter

Advanced Troubleshooting with Specialized Tools

Standard optical troubleshooting tools cannot be used on a live PON because the test wavelengths would interfere with the live traffic and the traffic signals would distort the test results. Therefore, specialized tools are required:

- **PON Power Meter:** Measures the power levels of different wavelengths independently. A PON power meter can measure the 1310 nm (upstream), 1490 nm (downstream), and 1550 nm (video) wavelengths simultaneously, helping to quickly determine if a signal is present at the ONT.
- **In-Service OTDR (Optical Time Domain Reflectometer):** An in-service OTDR is a custom-built device that uses a test wavelength outside of the live traffic wavelengths (typically 1625 nm or 1650 nm). This allows technicians to perform a fiber trace and locate faults like breaks or high-loss splices without disrupting service to other customers. The OLT is designed to ignore signals in this wavelength range, ensuring no interference.

Recommended Troubleshooting Steps

- **Initial Assessment:** The NOC receives an alert or a customer report. By checking the network map, they determine the number of affected users, which indicates the likely fault location (e.g., a single drop, a single splitter, or the entire feeder).
- **On-Site Diagnosis:** A technician is dispatched. The first step is to use a PON power meter to check if the signal is reaching the affected point.
- **Advanced Analysis (if needed):** If the PON meter shows no signal, an in-service OTDR can be used from the nearest access point (e.g., the splitter or the ONT location) to precisely locate the fault.
- **Repair or Replacement:** Once the fault is located, the necessary repair or equipment replacement is performed.

3.7.2 ONT Hardware Features and Indicators

ONT Functions and Features

An Optical Network Terminal (ONT) is the customer-side device that terminates the GPON network.

- **Upstream:** The ONT's Passive Optical Network (PON) port connects to the OLT to transmit data and voice traffic.
- **Downstream:** The ONT receives data, voice, and video signals and distributes them to end-user devices through various ports.
- **User Interfaces:** ONTs typically offer multiple ports for different services, such as:

Fig. 3.7.7. ONT Rear Panel

  - Ethernet Ports (RJ-45): For connecting devices like PCs, LAN switches, and STBs for internet and IP-related services (10/100/1000 Base-TX).
  - POTS Ports (RJ-11): For connecting telephones or fax machines for voice and fax services.
  - RF Video Port: For analog video services (optional).
- **Wi-Fi Capability:** Many modern ONTs can be configured to act as a residential gateway (RGW) to provide Wi-Fi access to multiple users.
- **Remote Management:** ONT software can be upgraded remotely through a Local Management Interface (LCT) or a centralized Element Management System (EMS).

UTL PON Splitter Specifications

Parameter	Unit		
Type	-	1 X 4	1 X 8
Operating wavelength	Nm	1260-1360 / 1480-1580	
Insertion Loss	dB	≤ 7.1	≤ 10.5
Uniformity	dB	0.5	0.8
PDL (max)	dB	<0.2	<0.2
Return Loss / Directivity	dB	>55	>55
Fiber Type	Single mode fibre, G.652/G.657A		
Working Temperature	°C	-40 to +85	

LED	Name	Status	Description
WIFI	WIFI service	On	WIFI function is enabled.
		Off	WIFI function is disabled.
ALM	Alarm indicator	On (red color)	Alarm indication on ONT
		On (green color)	ONT does not have any alarm
PON	ONT Ranging Status in GPON network	On	ONT is ranged with OLT
		Off	ONT is not ranged with OLT

Port	Function
Optical (OPT) port	One optical port for PON link connectivity to OLT.
GbE1 to GbE4	RJ-45 port: Ethernet interface to connect PC, Set top box or LAN switch through Ethernet cable. All ports supports 10/100/1000 Mbps in auto negotiation mode.
Ph1 & Ph2	To provide two voice telephone ports to connect to a phone or a FAX, so as to provide Voice and FAX services.
12VDC	To connect 12V DC Power supply through ONT CCU or AC/DC power adaptor
Power On/Off	ONT power ON/OFF switch to turn ON and OFF.
USB Port	To connect USB devices like printer etc.
RST	To Reset ONT (Soft reset only)

LED	Name	Status	Description
PH-1	Phone	On	Voice port is enabled.
		Off	Voice port is disabled.
PH-2	Phone	On	Voice port is enabled.
		Off	Voice port is disabled.
PWR	Power	On	ONT Power supply is ON
		Off	Power supply is switched off

No.	LED status (LED Port Name)					Description
	GE-1	GE-2	GE-3	GE-4	GE-5 (VEIP)	
1	Green Glowing	Green Glowing	Green Glowing	Green Glowing	No LED	Physical Link Up
2	Amber Glowing	Amber Glowing	Amber Glowing	Amber Glowing	No LED	Logical link up with end device
3	Amber Blinking	Amber Blinking	Amber Blinking	Amber Blinking	No LED	Traffic flow @ various speed

CCU Monitoring Panel Indicators

A Charge Controller Unit (CCU) is a vital component of the power system for the ONT at sites with solar power. Its front panel indicators provide a quick visual status check of the power system.

Battery Level LEDs:

- Green: Indicates the battery is in a healthy charge range (e.g., 75-100%, 50-75%, 25-50%).
- Red: Indicates a low battery charge (below 25%). The ONT may be turned off if both AC and solar power inputs are absent.

Mains (AC) Indicators:

- **Mains I/P Normal (Green):** Indicates that the AC power input is within the normal operating voltage range.
- **Mains Charge (Amber):** Indicates the battery is being charged by the AC power source.
- **Mains I/P Over/Under Voltage (Red):** Indicates that the AC input voltage is outside the safe operating range.

Solar Panel Indicators:

- **Solar Charge (Amber):** Indicates the battery is being charged by the solar panel.
- **Solar Panel Reverse (Red):** Indicates that the solar panel wires are connected with reverse polarity, which requires immediate correction.
- **Solar OV / Fault (Red):** Indicates a high voltage or a fault from the solar panel.

Battery Indicators:

- **Battery Reverse (Red):** Indicates that the battery is connected with reverse polarity, which can damage the equipment.

These indicators are crucial for on-site technicians to quickly diagnose power-related issues without needing additional test equipment.

Fig. 3.7.8. Highlighted LED's are glowing when AC & Solar Present

Fig. 3.7.9 Highlighted LED's are glowing when AC only Present

Fig. 3.7.10. Highlighted LED's are glowing when AC & Solar Present

Fig. 3.7.11. Hybrid SPV Power System for ONT

Notes

UNIT 3.8: ONT Status Check

Unit Objectives

By the end of this unit, the participants will be able to:

1. Perform ONT status check and interpret the results to ensure proper functionality.
2. Verify LED indicators on ONT and CCU devices to assess operational status and identify faults.
3. Conduct CCU status verification and understand its role in ONT power supply and operation.
4. Report faults accurately and apply corrective measures based on observations and system diagnostics.
5. Configure ONT services, including IP settings, VLANs, and other service parameters as per network requirements.
6. Carry out preventive maintenance of ONT and troubleshoot common issues to maintain reliable network performance.

3.8.1 ONT Status Check

ONT in the real time will be monitored by executive at the panchayat's location. The ONT performance will vary as and when the link goes down with OLT, Splitter. There are other consequences that ONT could fail in the field. So checking the ONT status is primary concern for the Village level executive. Below listed few steps to find out the status of ONT.

Checking for ONT Rear Panel correctness as per below Specification/ tables references:

LED	Name	Status	Description
WIFI	WIFI service	On	WIFI function is enabled.
		Off	WIFI function is disabled.
ALM	Alarm indicator	On (red color)	Alarm indication on ONT
		On (green color)	ONT does not have any alarm
PON	ONT Ranging Status in PON network	On	ONT is ranged with OLT
		Off	ONT is not ranged with OLT

LED	Name	Status	Description
PH-1	Phone	On	Voice port is enabled.
		Off	Voice port is disabled.
PH-2	Phone	On	Voice port is enabled.
		Off	Voice port is disabled.
PWR	Power	On	ONT Power supply is ON
		Off	Power supply is switched off

No.	LED status (LED Port Name)					Description
	GE-1	GE-2	GE-3	GE-4	GE-5 (VEIP)	
1	Green Glowing	Green Glowing	Green Glowing	Green Glowing	No LED	Physical Link Up
2	Amber Glowing	Amber Glowing	Amber Glowing	Amber Glowing	No LED	Logical link up with end device
3	Amber Blinking	Amber Blinking	Amber Blinking	Amber Blinking	No LED	Traffic flow @ various speed

Verifying the LEDs in CCU Monitoring panel indicators

Fig. 3.8.1. Charge Coupler Unit

Fig. 3.8.2. Charge Coupler Unit with LED

Check for :

- Mains Charge: Amber LED should be ON when battery is being charged through AC.
- Mains I/P Normal: AC mains is in operating range the LED will be ON & Green.
- Solar Charge: Amber LED should be ON when battery is being charged through Solar Input.

Issues if:

- Mains I/P Over Voltage: AC voltage above the operating voltage level; LED is RED.
- Mains I/P Under Voltage: AC voltage below the operating voltage level; LED is RED.
- Mains O/P OL: High current is being derived on AC mains.
- Mains O/P OV: High voltage is being delivered for battery charging; LED is RED.
- Solar Panel Reverse: When SPV panel wires are connected with reverse polarity the LED will be RED.
- Solar OV / Fault: This shows the either the Solar panel voltage is high or not available. The LED will be RED in such conditions.
- Battery Reverse: If LED is RED, this indicates that the Battery is connected in reverse polarity and action is required accordingly.
- Checking the Battery level: Battery level should be under green LED
- Various levels are displayed through LEDs as shown below:
- 100 - 75: Battery charged level is between 75 to 100 % and the LED will be ON Green.
- 5 - 50: Battery charged level is between 50 to 75 % and the LED will be ON Green.
- 50 - 25: Battery charged level is between 25 to 50 % and the LED will be ON Green.
    - Low: Battery charged level is below 25 % and the LED will be
    - RED. In this condition the ONT will be off or otherwise if ONT is on the same should be made off if

Identification of power modes:

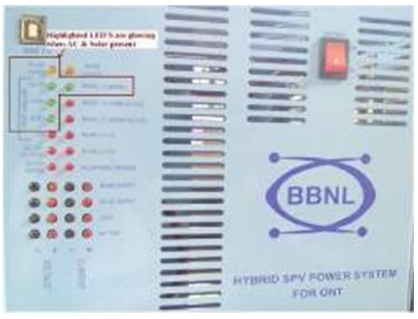


Fig. 3.8.3. Solar & AC Present

Fig. 3.8.4. Solar Present

Fig. 3.8.5. AC Present

Notes

UNIT 3.9: ONT Service Configuration

Unit Objectives

By the end of this unit, the participants will be able to:

1. Perform ONT service configuration to enable required network services for end-users.
2. Configure ONT High-Speed Internet (HSI) settings to ensure proper internet connectivity.
3. Set up ONT WiFi configuration, including SSID, security settings, and access parameters.
4. Configure ONT IPTV service to enable video broadcasting and interactive TV features.
5. Configure ONT VoIP service to enable voice communication over IP networks.

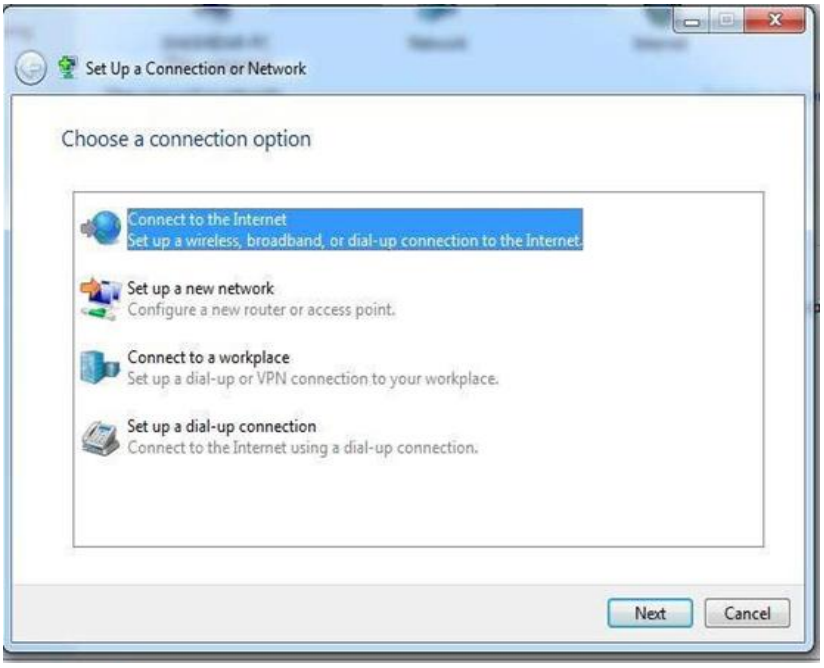
3.9.1 HSI Service Configuration

- Verify from the central office that HSI connection is already configured through LCT/EMS in central office on the Ethernet port of ONT11.
- Connect one end of an Ethernet (LAN) cable to the corresponding Ethernet port of ONT11 and its other end to a PC or laptop as per requirement.
- On the PC, open Network Sharing Centre by pressing the start menu button on the left side of Desktop screen and selecting Control Panel option.

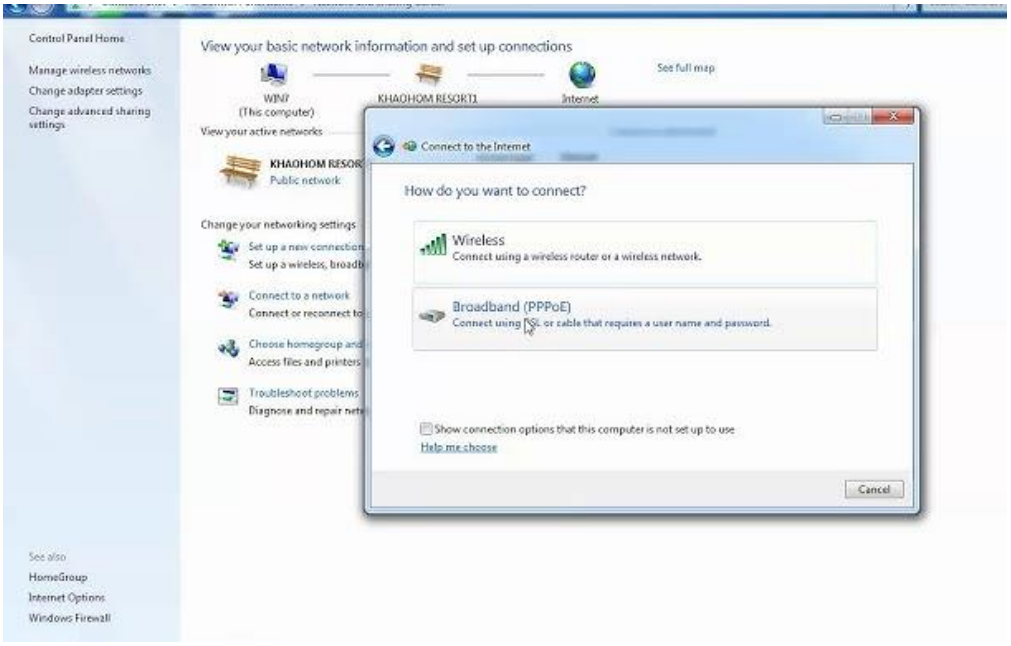
PC Connection for Internet configuration

- Once you have the Control Panel window open, select the Network and Internet Option and then the Network Sharing Centre option in the subsequent window.

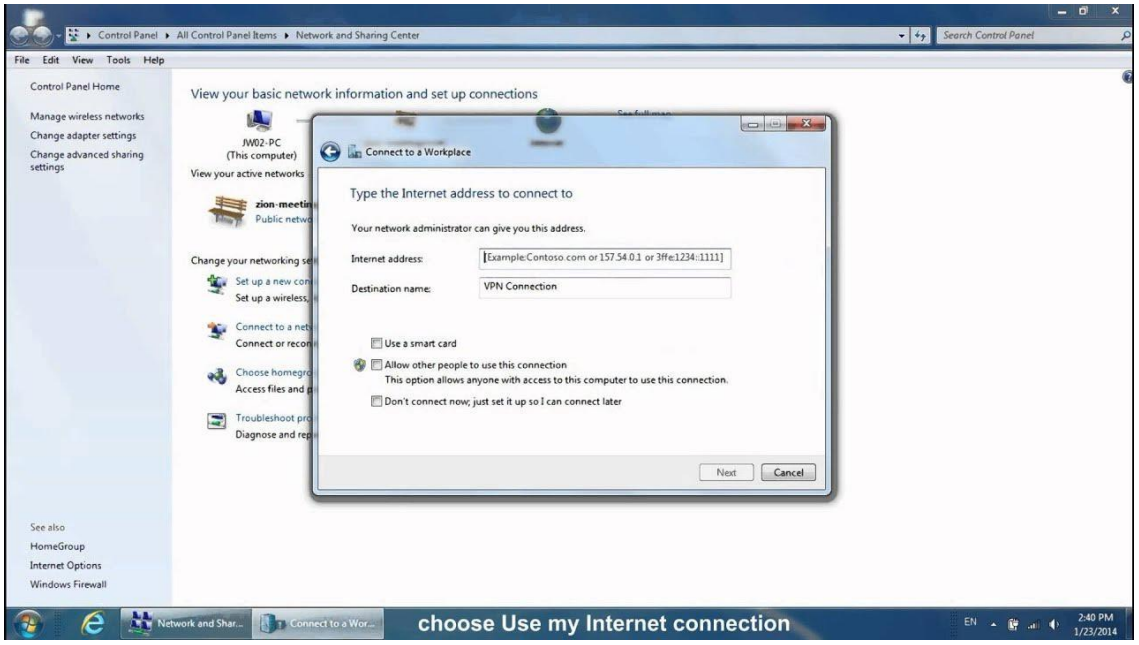
- In the Network Sharing Centre window, under the 'Change your networking settings tab', select the 'Set up a new connection' option and click on 'Next' in the subsequent window.



Select the Broadband (PPPoE) option from the current window as shown below.



Now you will have a window where you need to enter the User name and password as provided by your service provider and once you have entered all the relevant details click on 'Connect' and you are ready to avail the Internet service.

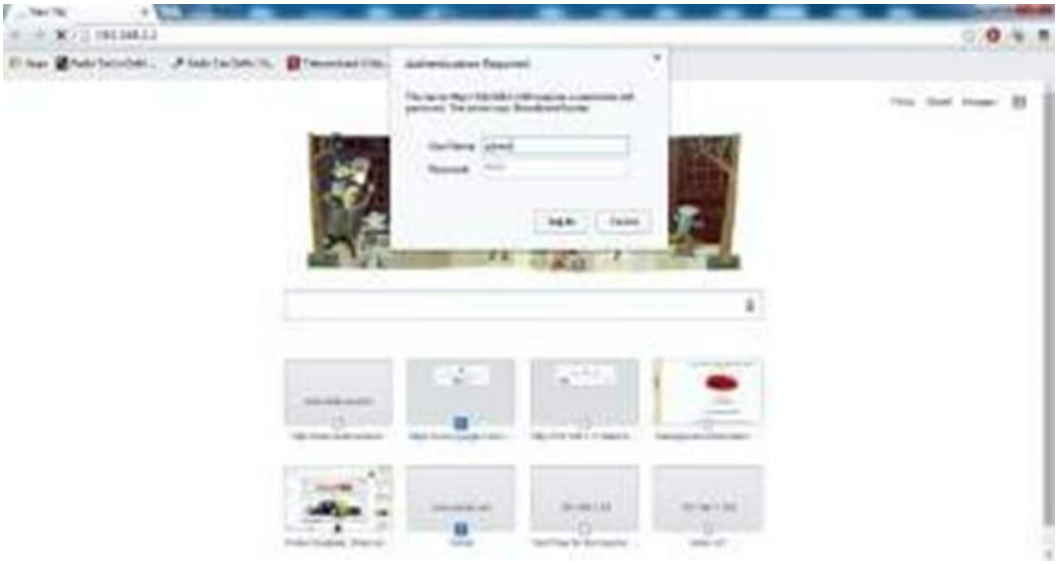


3.9.3 Configuration of PPPoE Service

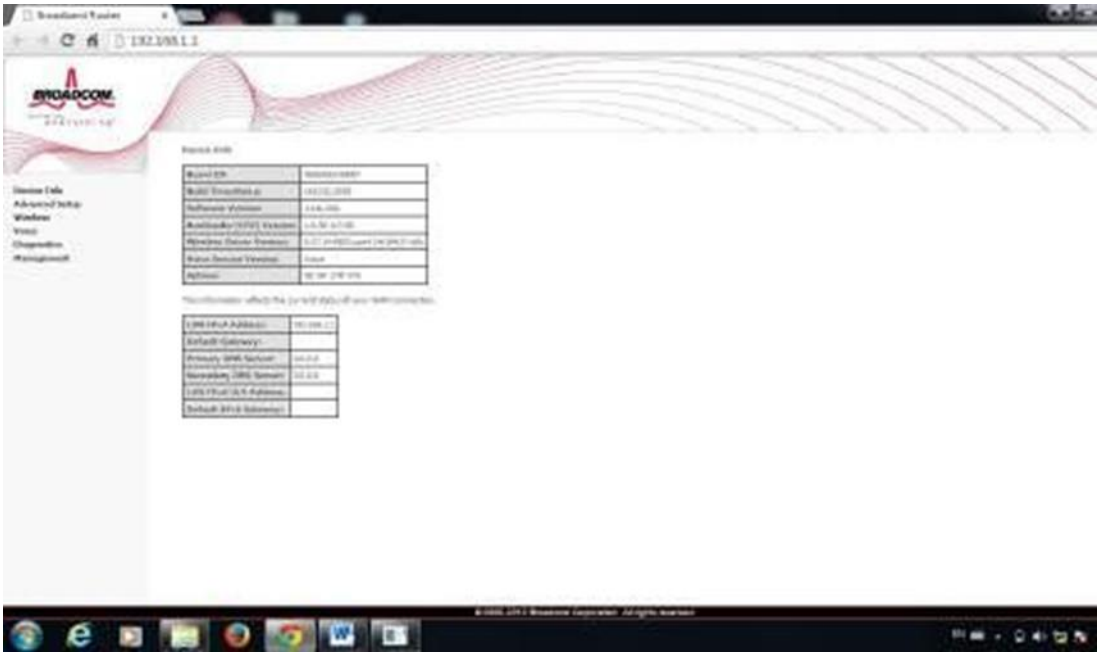
Connect the PC/Laptop to any Ethernet port on ONT. Further configuration to be done as per following steps: -

1. Configure a PC / Laptop in DHCP mode and connect it to one of the LAN ports of ONT on which PPPoE connection is already created, so that it gets an IP from the Residential Gateway.
2. Go to command prompt in connected laptop and check the received IP by typing "ipconfig" in Windows and "ifconfig" in Linux. It will receive an IP from the subnet with network ID 192.168.1.x.
3. Open an Internet browser in the connected laptop / PC. Browse the following site: http://192.168.1.1.
4. The ONT Gateway Config page will open and ask for user name and password. Login with Username:
5. “admin” and Password: “admin”. Enter these fields and click login button
6. Open the ONT Gateway Configuration page and further configuration is to be done in the following steps.

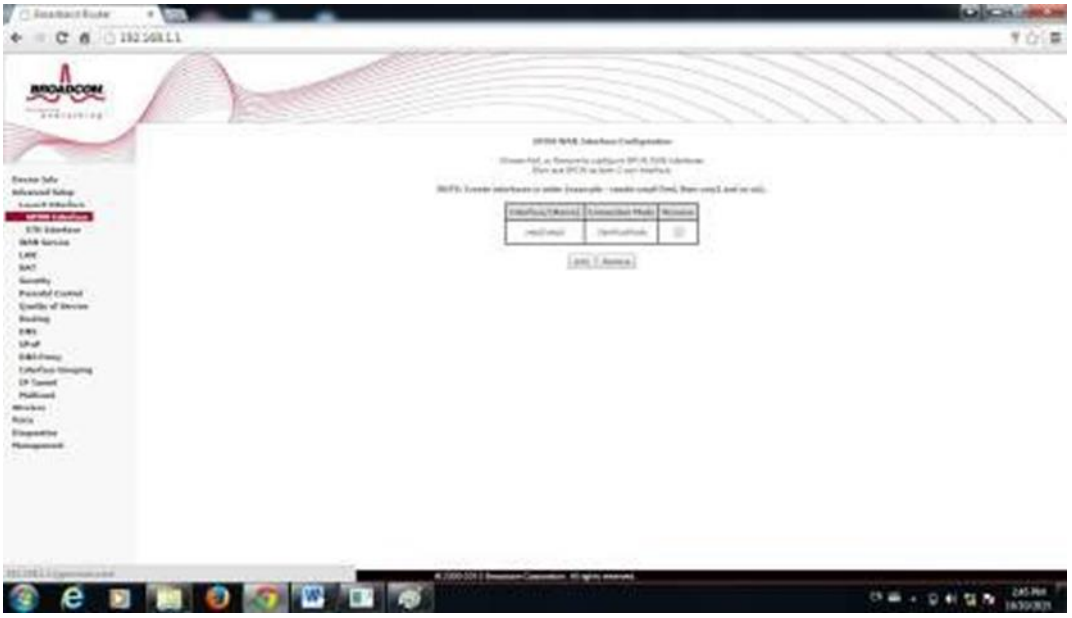
User name and password is required to start this configuration



On the ONT Gateway Configuration page select 'Advance Setup' in the left side menu.

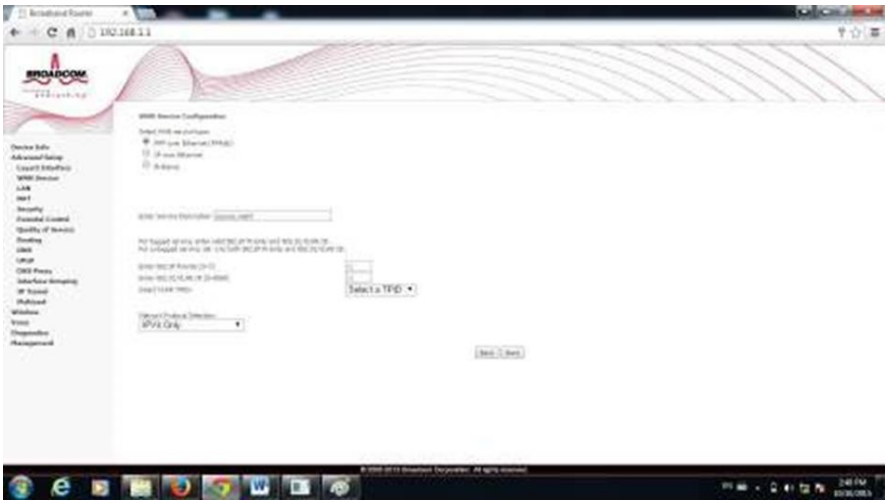


Then select Layer 2 Interface and select GPON Interface in the sub-menu.

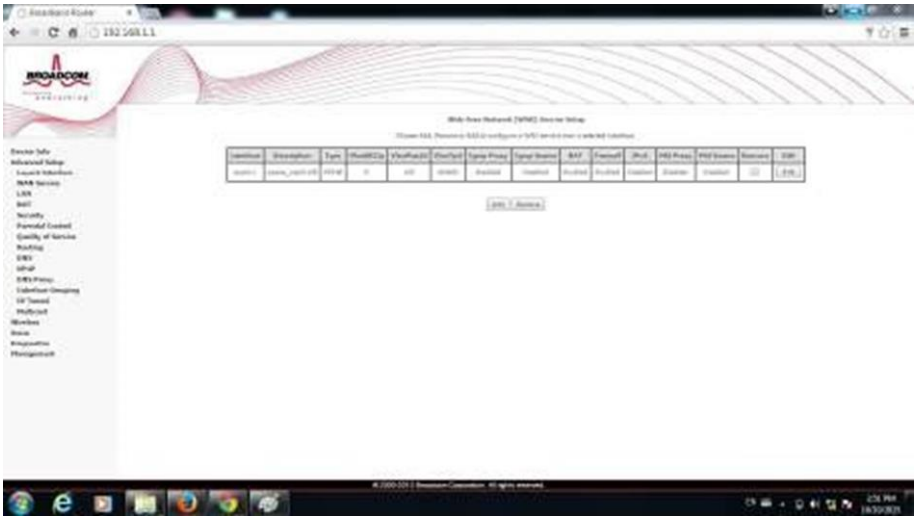


On the above page, click on Add and then Apply/Save on page mentioned below.

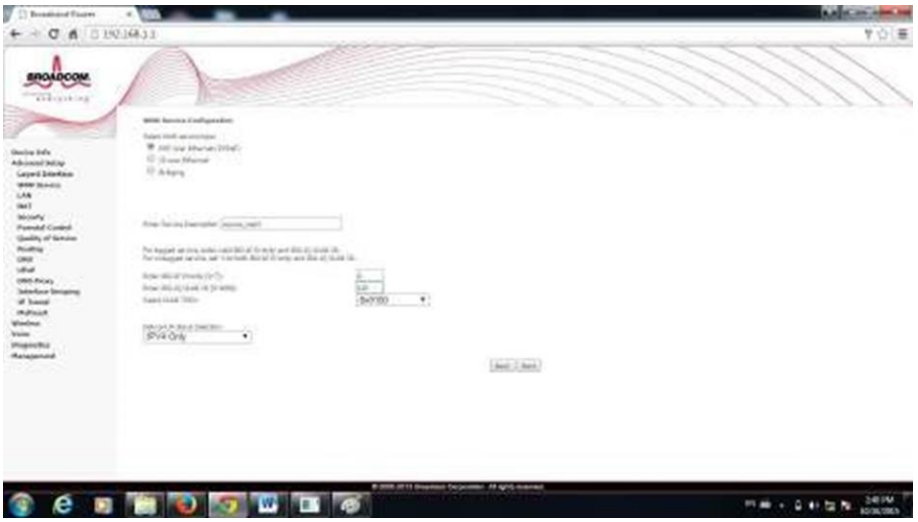
Then, go to WAN Service on the left side menu. On the right side a page titled WAN Service Setup will appear.



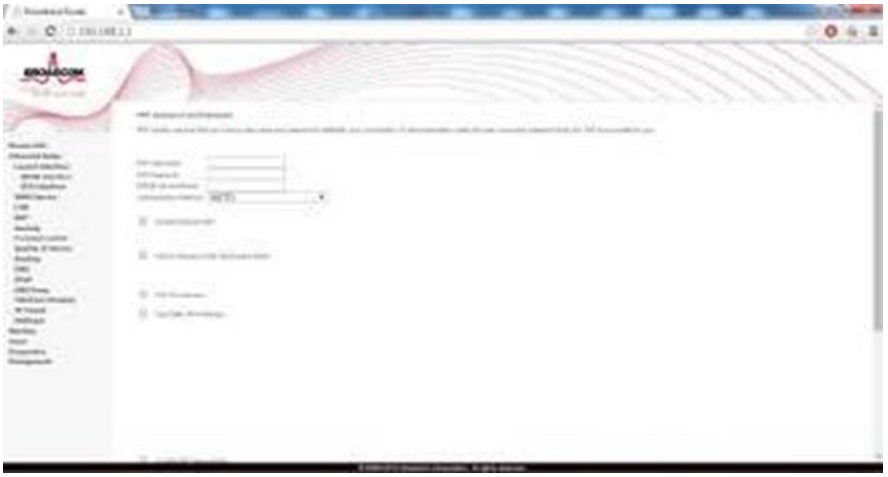
If there is a row in the service table, select remove check box in the 2nd last column in the row and then press remove button below the table.



For PPPoE Service Configuration, select PPPoE radio button else select IP over Ethernet.



In the text boxes below, provide VLAN ID and P-bit of the connection



Press next

Provide information on the next pages as per the service preference Finally Press Apply/Save. then close the window.
Now the ONT is ready for use with PPPoE connectivity and can be used for accessing the internet

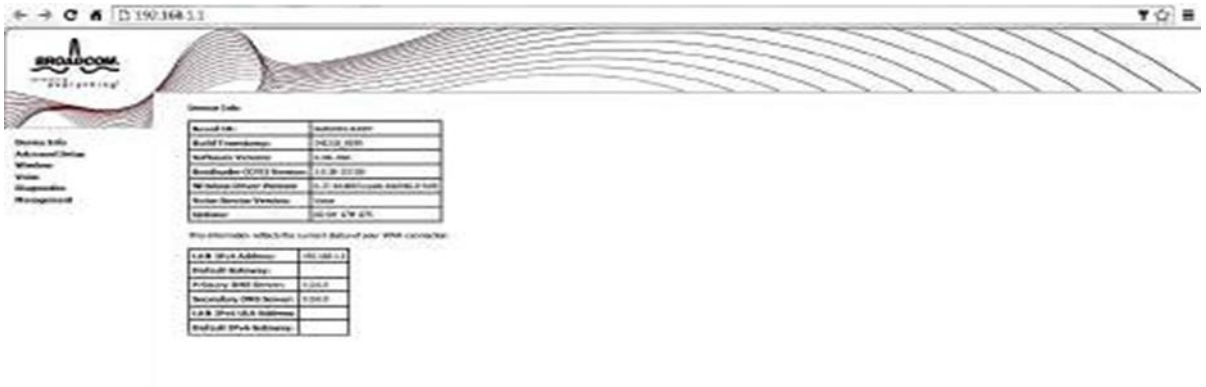
3.9.4 Configuration of Wi-Fi Service

After login in to 192.168.1.1 from configuring system:

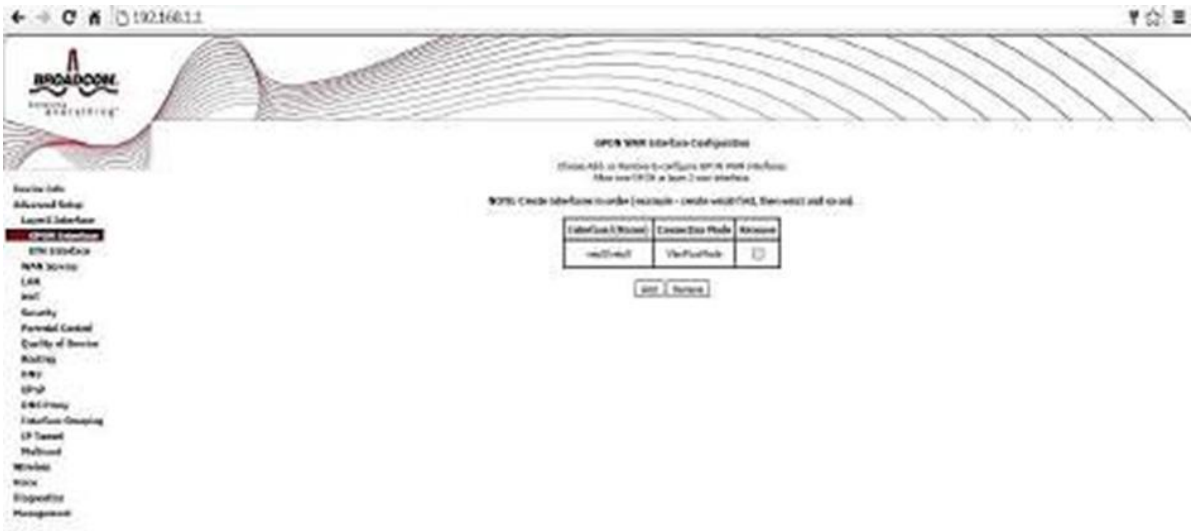
1. Select Wireless in the left side menu.
2. Then select Basic in the sub-menu.
3. On the page, select “Enable Wireless” and provide the SSID in the space provided below.
4. Select “India” in the country menu.
5. Uncheck guest access points if you desire not to configure them.
6. Press Apply/Save.
7. Now select “Security” in the Wireless sub-menu.
8. Select Network Authentication type and Encryption and click Apply/Save.
9. Now the ONT is ready for use with Wi-Fi connectivity and can be used for accessing the internet. Now enable the Wi-Fi port on Laptop to connect to the Wi-Fi network of ONT11

Wi-Fi Configuration at ONT site level on Mobile:

1. After configuring WIFI setup at OLT we have to do the WiFi setting at ONT
2. Enable Wifi mode In Mobile
3. Detect the Wifi Name & Select the Wi-Fi {wifi name configured will be shared }
4. Open Google/Mozilla/IE browser
5. Enter 192.18.1.1. on browser tab by entering link on browser opens up Configuration page
6. Select 'Advance Setup' in the left side menu

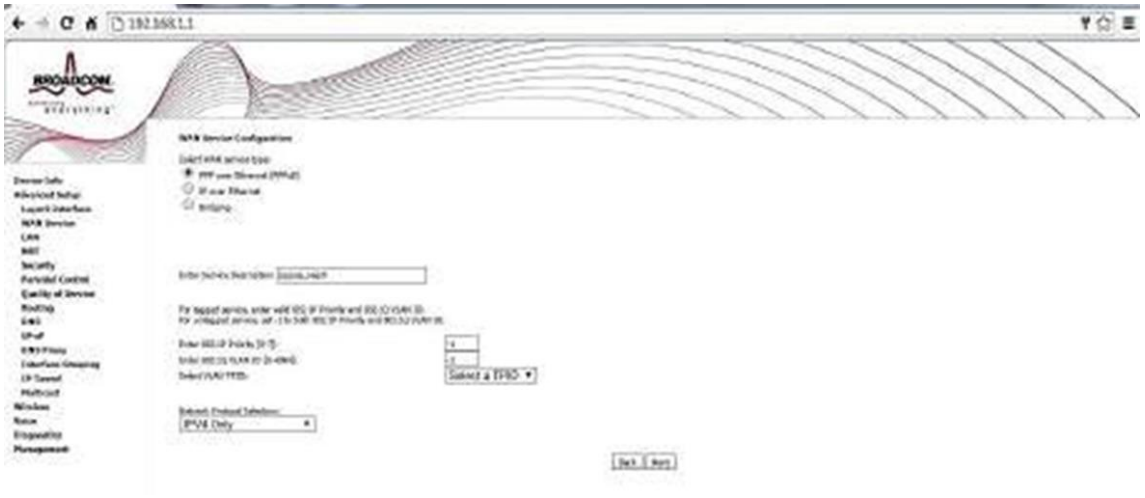


Then select Layer2 Interface and select GPON Interface in the sub-menu.

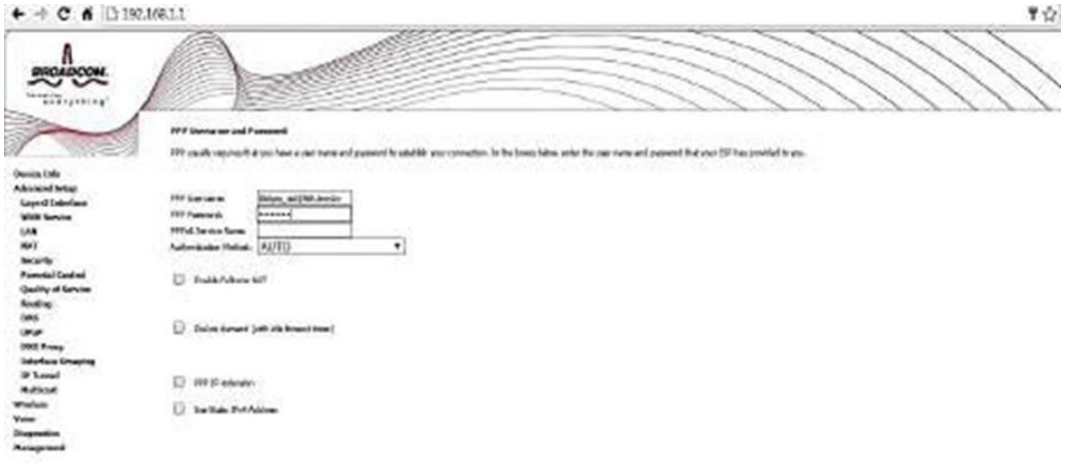


On the above page, click on Add and then Apply/Save on page mentioned below:

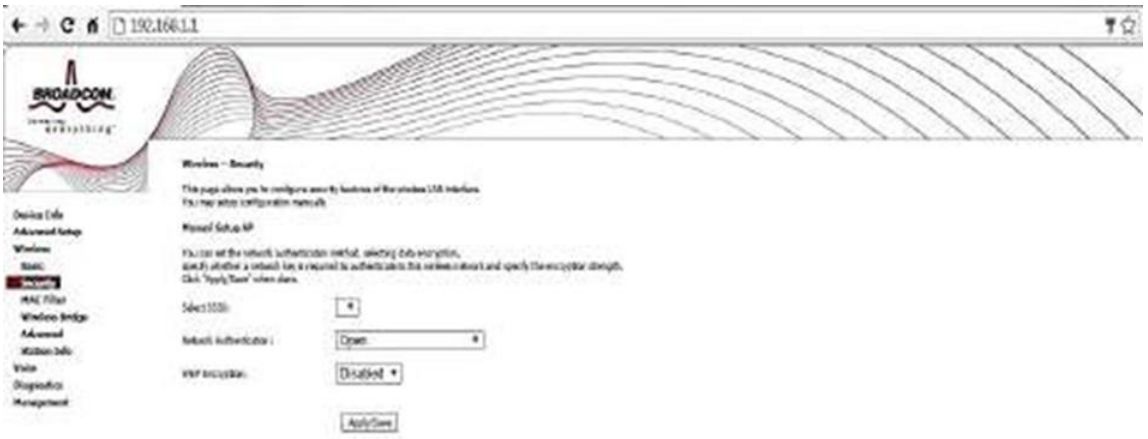
Then, go to WAN Service on the left side menu. On the right side a page titled WAN Service Setup will appear, select as shown:



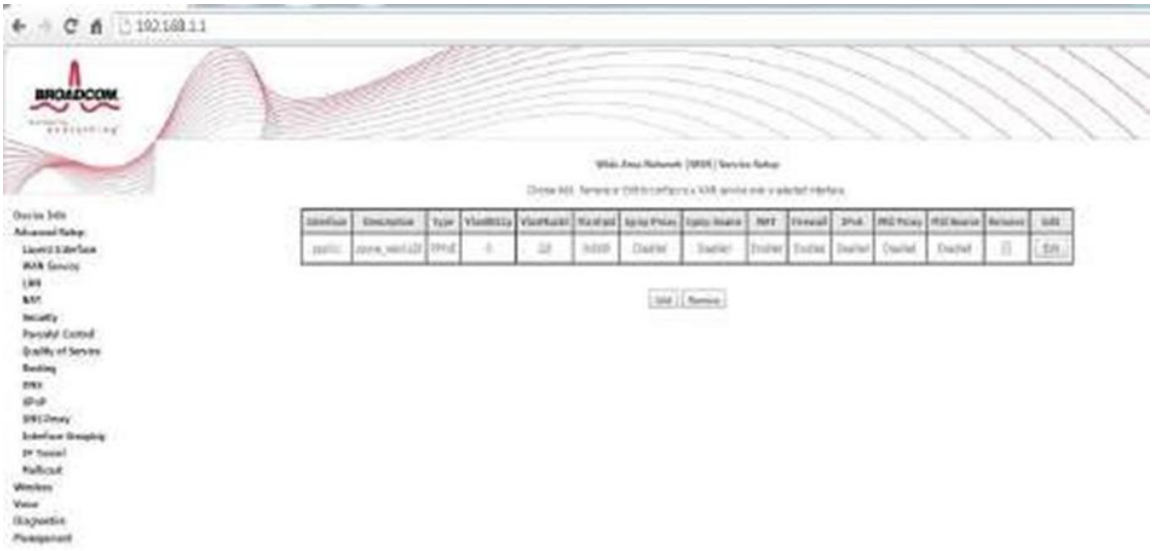
Enter Username and Password



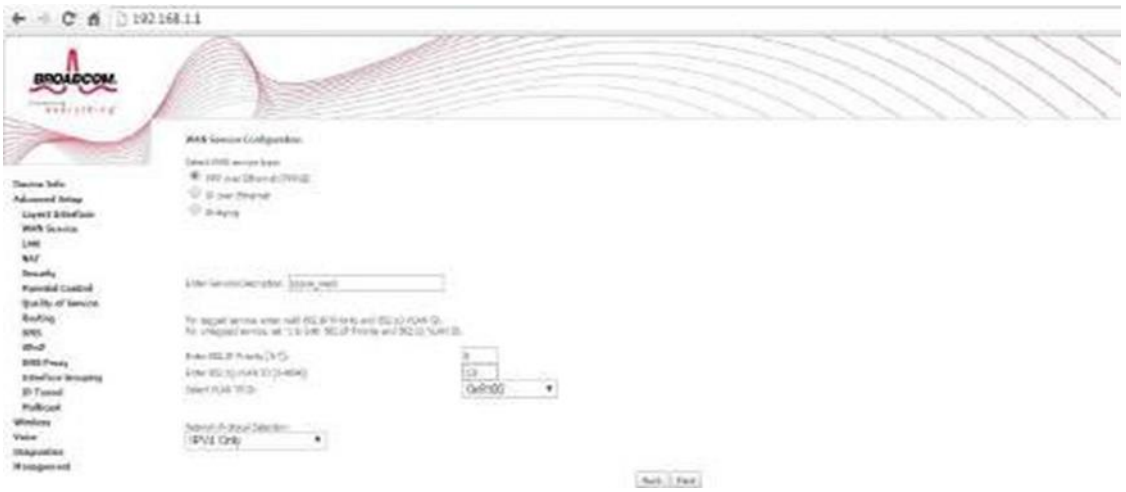
Select SSID Apply and save



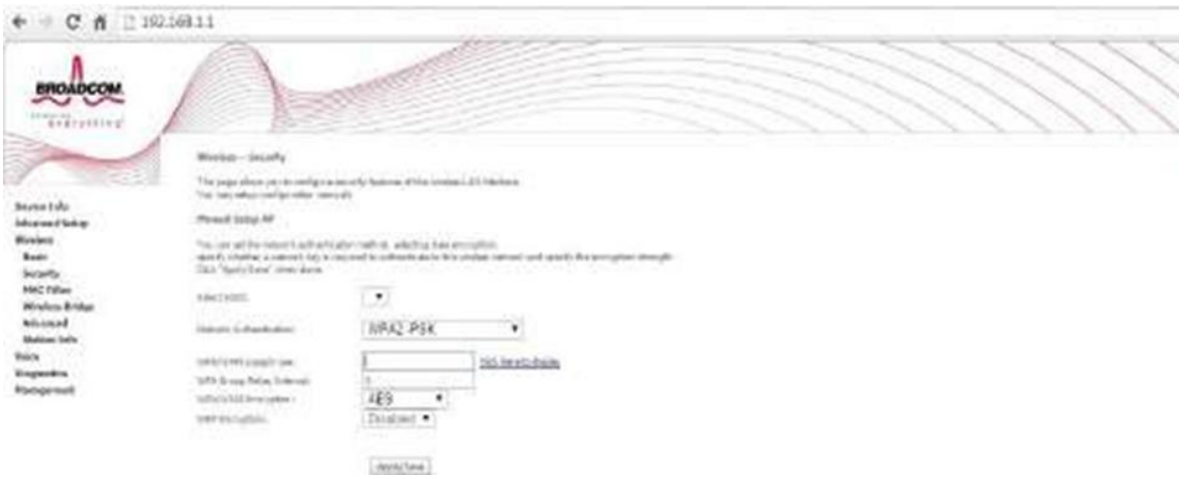
If there is a row in the service table, select remove check box in the 2nd last column in the row and then press remove button below the table.



In WAN configuration enter the VLAN TPID as 0x8100



Apply



3.9.5 IPTV Configuration

Make the connection as shown in the connection diagram. once the OLT engineer provide access the set up will start working.

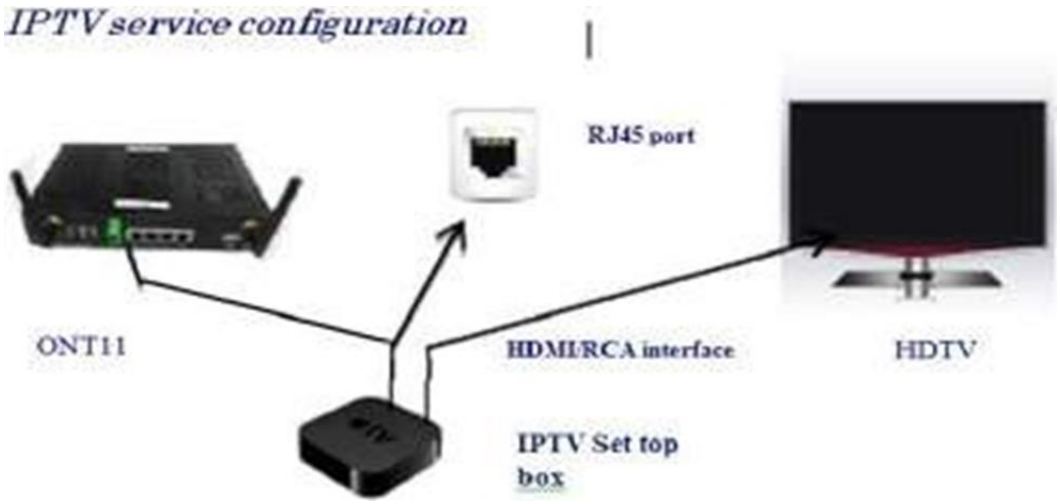


Fig. 3.9.1: TV Connection for IPTV

3.9.6 Phone (Voice)/FAX Service Configuration

Notes

UNIT 3.10: ONT Preventive Measurements

Unit Objectives

By the end of this unit, the participants will be able to:

1. Discuss the applicable ONT preventive measurements.

3.10.1 ONT Preventive Measurements

1. Always cover optical patch cord open end and put cap on optical port of ONT when fiber cable is not connected.
2. Connect only matching optical connector (SC/APC), generally green in colour to ONT optical port also with green color.
3. ONT should only be connected to network fiber when its optical power is received between -10dBm to
4. Patrolling Practices-Dealing with SFP/SFP+

SN	Do's
1.	Always handle SFP/SFP+ with clean hands
2.	Keep cover on SFP while handling/ dealing with any SFP.
3.	Always ensure the right SFP is being put in correct slot.
4.	Insert the SFP into the receptacle on the card in right position.
5.	Always check the correct position before inserting the same to slot.
6.	Slide the SFP into the receptacle until you hear a click, indicating that the SFP is securely seated in the receptacle.
7.	Always ensure the SFP is locked in to receptacle and the locking leaver is pushed to its position.
8.	Before pulling out the SFP, unlocking leaver should be pulled out.
9.	Always apply only required force while inserting the SFP or jacking out the same.
10.	Always keep all unused optical ports of SFP/SFP+ covered when not connected to a mating cable.
11.	Enable ALS (automatic laser shutdown) feature if it is disable.
12.	Any optical patch cord connected to any of the optical interface should always be capped on loose end.

Patrolling Practices-Dealing with SFP/SFP+

SN	Don'ts
1.	Do not allow dust or moisture to SFP/SFP+
2.	Do not remove the SFP optical port cover before connecting to patch cord.
3.	Do not insert any SFP/SFP+ into any slot.
4.	Do not insert SFP/SFP+ into wrong slot.
5.	Don't force if SFP is not going in and check the correct position/direction
6.	Do not insert SFP/SFP+ loosely into the receptacle.
7.	Do not leave SFP in unlock position in receptacle
8.	Do not try to pull SFP without unlocking it.
9.	Do not try to insert or jack out the SFP forcefully otherwise the locking leaver will be damaged
10.	Do not leave SFP/SFP+ ports uncovered when fibre is not connected to avoid dust into SFP optical ports.
11.	Do not look into SFP/SFP+ when system is powered up. The signals coming out of SFP/SFP+ can be dangerous to eyes.
12.	Do not leave loose end of patch cord open it may cause harm to human eyes.
13.	Do not loop SFP Tx. / Rx. Ports through patch cord without using required attenuator pad.

Patrolling Practices-Handling the fiber cable

Dos	Don'ts
When handling fiber cables, take the precautions to prevent damage to the cables:	Do not allow the cables to kink.
Maintain a minimum bend radius of 1.5cm.	Do not bend fibre excessively.
When you disconnect fiber cables, always pull out by holding the connector.	Do not pull out the cable while disconnecting fiber cables.
Keep all fibre-optic connectors covered when not connected to a mating cable.	Do not look into fibre-optic connectors or cables. The signals on fibre-optic connectors and cables can be hazardous to eyesight.
Always clean fibre connector properly before connecting to optical ports.	Do not connect the fiber patch cord to optical interface without cleaning the connectors.

Notes

UNIT 3.11: ONT Maintenance and Troubleshooting

Unit Objectives

By the end of this unit, the participants will be able to:

1. Discuss the ONT registration failures and applicable solutions.

3.11.1 ONT- Registration Failures and Solutions

Some of the major and usual real time errors and corresponding actions are listed below ONT-Registration failure.

Fault Type	Possible Cause	Suggested Action
ONT Registration Failure	Check if the ONT power LED is ON and Green.	ONT electrical Power cable and CCU (SPV Power backup) to be verified. If power is not OK change the CCU or Power Adapter as the case may be. If power is OK, Off/ON the ONT and wait for Power LED to become ON. If power is OK and LED is off, the ONT is faulty. Replace the ONT.

Fault Type	Possible Cause	Suggested Action
ONT Registration Failure	Check if the ONT PON LED is ON and Green.	If PON LED is Off, check the ONT optical receive power is OK (-10 to -27 dBm). If power is not in the range check the fiber plant which includes cleaning of optical connectors. If optical receive power is OK, connect the fiber and restart the ONT. If still PON LED is off, check if fiber inside the ONT is connected properly at ONT PON port. Re-jack the same and cover back the ONT. Connect the fibre and restart the ONT. If it doesn't turn Green, please replace the ONT.

Fault Type	Possible Cause	Suggested Action
ONT Registration Failure	The physical distance of the ONT is not as per the set window	If the physical fiber distance of ONT ≤ 20 Kms, restart the ONT and check if ONT is ranging properly, otherwise replace the ONT. If the physical fiber length of ONT ≥ 20 Kms and ≤ 40 Kms, set the logical distance of PON at OLT to 40 Km under CM in PON Physical Reach window. Restart the ONT and check if ONT ranging is OK, otherwise replace the ONT. If the physical fiber distance of ONT ≥ 40 Kms, set the logical distance of PON at OLT to 60 Km under CM in PON Physical Reach window. Restart the ONT and check if ONT ranging is OK, otherwise replace the ONT. Note that if physical reach is changed no other ONT will be ranged on the PON outside the set window.

- Please check the system policy. If ONT discovery is directed by user, in that case ONT Serial number need to be registered at OLT first and
- ONT will range after the ONT Sr. No. is registered.
- Otherwise change the system policy to “Auto Discovery mode” and restart the ONT. If still the ONT is not coming up, replace the ONT.

ONT-Do’s and Don'ts

- Don't make direct eye contact with fiber.
- Make sure that fiber should not bend.
- Put the ONT11 on the place where no water and moisture present.
- Put the ONT11 out of reach of children.
- Don't place the ONT11 in direct sunlight.
- Use cable stacker for cabling.

Notes

UNIT 3.12: Record Repairs/Replacements

Unit Objectives

By the end of this unit, the participants will be able to:

1. Record repairs/replacements undertaken during fault rectification.

3.12.1 Data Recording

Successful network operations and maintenance for telecom organisations comprises not only optimizing communication networks but also the staff, procedures, and systems that manage and maintain telecom networks.

The procedure used to address faults by the Key Network Services Business Unit is known as fault detection, handling, and rectification (and does not include any commercial terms, rebates, compensation or other commercial arrangement which may be offered by a Business Unit in relation to any Fault or delay). This procedure begins with the Key Network Services Business Unit recording the fault. It includes testing, fault sectionalization (when facilities of another Carrier or Carrier Service Provider's network are involved), fault rectification and clearance, and fault rectification.

Recording alone is insufficient; record storage is also necessary:

- Data documentation at the plant location is crucial.
- Databases must be stored in a variety of formats, such as paper prints or digital files, and they must have numerous copies saved in various places so that each team has access to them.
- Ensure that it is available for review by all authorities.

The following reports must be submitted on a frequent basis to ensure status updates:

- Report on the status update
- Pending issues
- Challenges
- Faults & Serviceability
- NOC for cable integration
- Final Closure of the job

The NOC engineer will assist in the first investigation of events that result from monitoring, and perform the following duties:

- Keep a record of incidents and link them to the happenings.
- Use the proper workarounds.
- Coordinate resolution with other support levels, such as partners and vendors from outside sources.

Exercise

Short Questions:

1. List two advantages and two disadvantages of optical fiber.
2. Define Snell's Law.
3. What is the role of NMS in the maintenance of ONT?
4. Describe the NOFN Vision.
5. Explain Polarization in optics.
6. What are the typical services provided by an ONT at the Gram Panchayat level?
7. What is a Laser?
8. Explain the importance of preventive maintenance in CCU and SPV.
9. What does the term "interference" refer to in fiber optics?
10. Briefly explain the ONT site survey procedure.

Fill in the Blanks:

1. The refractive index profile describes the variation of _____ within the optical fiber core and cladding.
2. Chromatic dispersion causes the spreading of different _____ over time during transmission.
3. The critical angle is the minimum angle of incidence at which _____ occurs.
4. A device that emits light through electroluminescence is called a _____.
5. GPS stands for _____.
6. In GPON architecture, the optical line terminal (OLT) is located at the _____ side.

Multiple Choice Questions:

1. Why is fiber optics used in communication systems?
   a) High bandwidth and long-distance transmission
   b) Cheap installation
   c) Susceptible to electromagnetic interference
   d) Low-speed data transfer
2. Which of the following is an advantage of optical fiber?
   a) Large size
   b) High attenuation
   c) Immunity to electromagnetic interference
   d) Heavy weight
3. The operational frequency of fiber optics typically lies in the range of:
   a) 1 kHz – 1 MHz
   b) 10 GHz – 100 GHz
   c) 100 THz – 300 THz
   d) 1 MHz – 10 MHz
4. What does GPON stand for?
   a) General Purpose Optical Network
   b) Gigabit Passive Optical Network
   c) Global Protocol Optical Network
   d) Generic Private Optical Node
5. What is the function of EMS in telecom networks?
   a) Manage the energy supply
   b) Monitor and control network elements
   c) Only repair hardware faults
   d) Provide internet service to customers

Notes

4. Promote Usage of Telecom Devices & Provide Services

Telecom Sector Skill Council

TEL/N6228

Key Learning Outcomes

By the end of this module, the paricipants will be able to:

1. Explain the purpose and significance of the CSC Outreach Programme, and describe its role in extending digital services to rural and underserved communities.
2. Understand the concept of Network for Information & Communication Technologies (NICT) and its application in enhancing the effectiveness of Common Services Centres (CSCs).
3. Identify major Internet Service Providers (ISPs) and understand their role in enabling internet connectivity in various regions.
4. Demonstrate understanding of broadband technology, including types, usage, and the benefits of high-speed internet in promoting digital inclusion.
5. Analyze the impact of digitization in India, and discuss key government initiatives driving digital transformation across sectors.
6. Recognize and operate various digital devices such as smartphones, tablets, computers, routers, and modems commonly used for telecom and e-services.
7. Identify popular mobile and web-based applications, and understand the compatible devices and platforms required for effective usage.
8. Provide support for accessing and using various e-services, including government portals, online payments, and citizen service platforms.
9. Understand the structure and function of e-terminals and kiosks, and explain their role in delivering public services in remote locations.
10. Navigate and promote key utility apps and service links, helping users access essential digital resources like DigiLocker, mAadhaar, UMANG, BHIM, etc.
11. Understand the basics of electrical systems and their various types, relevant to powering telecom and digital devices.
12. Identify types of batteries and power banks, and explain their applications in maintaining device uptime and portability.
13. Understand the function and importance of UPS (Uninterruptible Power Supply) systems in ensuring uninterrupted power supply to critical telecom equipment.
14. Apply basic electrical maintenance practices to ensure the safe and effective functioning of digital and telecom infrastructure.
15. Demonstrate methods of revenue management and record maintenance, including proper documentation of service transactions and financial records to ensure accountability and transparency in CSC operations.

UNIT 4.1: Approach to Common Service Centers (CSC)

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the role and importance of the Common Service Centers (CSC) Outreach Programme in delivering digital services to rural and remote areas.
2. Describe the Network for Information & Communication Technologies (NICT) and its contribution to strengthening the CSC infrastructure and digital service delivery.
3. Identify major Internet Service Providers (ISPs) and understand their function in providing internet connectivity essential for CSC operations.
4. Understand broadband technology, its types, and its significance in ensuring reliable and high-speed internet access for CSC-enabled services.

4.1.1. The Common Service Centre (CSC) Scheme: Digital Inclusion in Rural India

The Common Service Centre (CSC) scheme is a flagship initiative under the Digital India program, aimed at making government and commercial services accessible to the rural population of India. Operating on a Public-Private Partnership (PPP) model, CSCs act as front-end delivery points for a wide array of digital services, bridging the gap between citizens and various government departments, banks, and private businesses.

What are Common Service Centres?

CSCs are essentially digital kiosks or centers managed by local entrepreneurs, known as Village Level Entrepreneurs (VLEs). They are designed to bring essential services to the doorstep of citizens, especially in remote and rural areas where access to technology and government offices is limited. The goal is to ensure accessibility, efficiency, transparency, and affordability of these services.

Services Offered:

The services provided through CSCs are categorized into three main areas:

- Government-to-Citizen (G2C) Services: This includes a wide range of government services like applications for birth, death, domicile, caste, and income certificates; Aadhaar enrollment and updates; ration card services; passport applications; and various social welfare scheme registrations, such as those related to pensions and scholarships.
- Business-to-Citizen (B2C) Services: These are commercial services offered by private companies. They include railway, airline, and bus ticket booking; mobile and DTH recharges; bill payments for electricity, water, and gas; and insurance services.
- Business-to-Business (B2B) Services: CSCs also facilitate services for other businesses, such as data entry, digital surveys, and other back-office support functions.

4.1.2 The CSC Ecosystem and Structure

The CSC program is managed by CSC e-Governance Services India Ltd. (CSC SPV), a Special Purpose Vehicle (SPV) incorporated under the Ministry of Electronics and Information Technology (MeitY), Government of India. The organizational structure is three-tiered:

- Village Level Entrepreneur (VLE): The VLE is the individual who operates the CSC at the village level. They are the key to the scheme's success, providing services directly to the citizens and acting as the main point of contact.
- Service Center Agency (SCA): The SCA is a private entity responsible for managing a cluster of 500 to 1,000 CSCs. They provide technical and business support to the VLEs and ensure the smooth delivery of services.
- State Designated Agency (SDA): The SDA is a state-level government body responsible for overall implementation and management of the CSC scheme within the state.

4.1.3 CSC 2.0: The Evolution of the Scheme

The CSC 2.0 scheme was launched in 2015 to expand the network and improve service delivery. The primary objective was to ensure at least one CSC in every Gram Panchayat (village council), taking the total number to 2.5 lakh (250,000) across India.

Key Objectives of CSC 2.0:

- Pervasive Access: To create a self-sustaining network of CSCs that can deliver a wide range of e-services to all citizens, particularly in rural areas.
- Empowerment of VLEs: To increase the sustainability of CSCs by ensuring a significant share of the service commission goes to the VLEs. There's also a strong push to encourage women to become VLEs, promoting economic empowerment.
- Centralized Technology Platform: To provide a single, robust technology platform for service delivery, making the process accountable, transparent, and traceable. This involves integrating various government and private services onto a unified portal.
- Institutional Framework: To strengthen the district-level governance structure for effective implementation and monitoring of the scheme.

The CSC scheme has evolved beyond just a service delivery platform. It now includes initiatives like Digital Village, which aims to create a comprehensive digital ecosystem in villages, and various skilling programs to enhance the capabilities of the rural workforce.

4.1.4 Internet Service Providers (ISPs) and Broadband

The original content's section on ISPs and broadband was outdated and not directly relevant to the CSC Outreach Programme. While crucial for the functioning of CSCs, this information is a separate topic.
Broadband refers to high-speed, reliable, and "always-on" internet access, which is foundational for the services offered by CSCs. An Internet Service Provider (ISP) is the organization that provides this internet access to the CSCs and their customers.

Broadband technologies have advanced significantly, with Fiber to the Home (FTTH) becoming increasingly common. The BharatNet project by the Government of India aims to connect all Gram Panchayats with high-speed fiber-optic connectivity, which is critical for the success and expansion of the CSC network, ensuring seamless delivery of digital services even in the most remote parts of the country.

Notes

UNIT 4.2: Digital Devices and Digital Approaches

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the concept of digitization and describe its progress in India.
2. Classify modern digital devices based on their functions and features.
3. Describe the role of mobile applications and associated devices in daily and professional use.
4. Identify and discuss modern e-services and the ways in which they are delivered.
5. Trace and explain the function and evolution of e-terminals and kiosks.

4.2.1 Digitization in India

Digitization is the process of converting information into a digital format. The Digital India program, a flagship initiative of the Government of India, goes beyond this, aiming to transform the country into a digitally empowered society and a knowledge economy. Its vision is to ensure that government services are accessible to every citizen electronically, fostering a truly connected and inclusive nation.

Key pillars and recent progress of the Digital India program include:

- Digital Infrastructure as a Core Utility: The government is expanding high-speed internet connectivity to even the most remote areas. The Bharat Net project, for instance, aims to connect all Gram Panchayats with broadband.
- Governance and Services on Demand: Platforms like UMANG (Unified Mobile Application for New-age Governance) and Digi Locker provide citizens with easy access to a wide range of government services and digital documents, reducing paperwork and improving transparency.
- Digital Empowerment of Citizens: Initiatives like Aadhaar have created a unique digital identity for a large majority of the population, which in turn facilitates seamless access to various services and direct benefit transfers (DBT).

The "Digitize India Platform" and "Digital Contributors" mentioned in the original text are part of an older, now-outdated initiative. The modern focus is on leveraging technologies like Artificial Intelligence (AI) and Blockchain to enhance governance, with the government's IndiaAI initiative focusing on developing AI solutions for agriculture, health, and urban management.

4.2.2 Digital Devices

Digital devices are the hardware tools that facilitate the consumption and creation of digital content. They have evolved significantly, becoming more compact, powerful, and interconnected.

1. Personal Computers (PCs)

A personal computer is a multipurpose electronic device designed for a single user.

- Desktop Computer: A non-portable PC that typically consists of a separate monitor, keyboard, mouse, and a main unit (tower or case). Desktops are powerful, easily upgradeable, and often used for demanding tasks like gaming, video editing, or professional work.
- Laptop: A portable PC with a "clamshell" form factor, integrating a screen, keyboard, and trackpad into a single unit. Laptops are designed for mobility and are a staple for students, professionals, and home users.

Types of Laptops:

The classification of laptops has become more fluid as technology has merged.

- Traditional Laptop: The standard clamshell design, optimized for general productivity and portability.
- Ultrabook / Thin-and-light Laptop: A marketing term for a class of high-performance laptops that are extremely thin and lightweight, often featuring long battery life. Examples include the Apple MacBook Air and various models from brands like Dell, HP, and Lenovo.
- 2-in-1s (Convertibles and Hybrids): These devices combine the functionality of a laptop and a tablet. A convertible typically has a hinge that allows the keyboard to be rotated 360 degrees to turn the device into a tablet. A hybrid or detachable has a keyboard that can be completely detached from the screen.
- Gaming Laptop: A high-performance laptop with a powerful processor, dedicated graphics card, and advanced cooling, designed specifically for playing video games. They are generally bulkier and have shorter battery life than other laptops.

2. Mobile Devices

Mobile devices are portable, handheld electronic devices, with smartphones and tablets being the most common.

- Smartphone: A mobile phone that combines a cellular phone with a computing operating system, offering internet access, multimedia capabilities, and the ability to run mobile applications. Modern smartphones are primarily controlled via touchscreens.
- Tablet: A larger, portable touch-screen device that is primarily used for media consumption, light productivity, and browsing. While some high-end tablets can function as laptop replacements, they are generally distinct from smartphones due to their larger size and lack of integrated cellular calling features.

Smartphone Operating Systems (OS)

An operating system is the core software that manages all the hardware and software on a device. The mobile OS market is dominated by two major players:

- Android: Developed by Google, Android is the most popular mobile OS globally due to its open-source nature and wide range of device options at various price points. It offers extensive customization, a vast app ecosystem (Google Play Store), and is used by countless manufacturers like Samsung, Google, Xiaomi, and OnePlus.
- iOS: Developed by Apple, iOS is a closed-source OS used exclusively on Apple's devices, such as the iPhone and iPad. It is known for its seamless integration with Apple's hardware and ecosystem, strong security features, and a highly curated app store (App Store). While offering less customization than Android, it provides a consistent and user-friendly experience.

Other mobile operating systems, such as Windows Mobile and BlackBerry OS, are now obsolete and have a negligible market share.

4.2.3 Apps & E-Services

- Mobile Applications ("Apps"): These are software programs designed to run on mobile devices. Apps have become central to modern digital life, providing services for communication, entertainment, banking, and more.
- E-Services: The delivery of services electronically. The CSC network in India is a prime example of an e-service delivery model. Examples include:
  - Financial Services: Mobile banking apps, UPI (Unified Payments Interface), and digital wallets like PhonePe, Paytm, and Google Pay have revolutionized payments.
  - Government Services: The aforementioned DigiLocker, UMANG, and other state-specific portals allow citizens to apply for certificates, pay taxes, and access public records online.
  - Utility Bill Payments: Consumers can now pay for electricity, water, and gas through various online portals and apps, eliminating the need to visit physical offices.
  - Digital Commerce: E-commerce platforms like Flipkart and Amazon, as well as the government's Open Network for Digital Commerce (ONDC), allow businesses to reach a wider audience and consumers to shop online.

4.2.4 E-Terminals & Kiosks

An e-terminal or kiosk is an interactive, standalone electronic device designed for public use and placed in a public location. They are designed to provide services to users without the need for direct human assistance. They have evolved from simple information terminals to sophisticated transaction platforms.

- Function: Kiosks streamline processes by providing a self-service option. They are equipped with a combination of hardware components like touchscreens, barcode scanners, card readers, printers, scanners and specialized software to facilitate transactions and information delivery. Kiosks are typically placed in public spaces like railway stations, airports, shopping malls, and government offices.
- **Common Applications:**
  - Self-Service Banking: ATMs (Automated Teller Machines) and cash deposit machines are a classic example.
  - Ticketing and Check-in: Automated kiosks at airports and railway stations for printing boarding passes or tickets.
  - Bill Payments: Kiosks at utility offices or public spaces that allow users to pay bills with cash, cards, or UPI.
  - Information and Wayfinding: Interactive maps and directories in large public buildings.
  - Government Services: The CSCs often function as a form of e-kiosk, providing a one-stop-shop for a wide range of services, including providing G2C (Government-to-Citizen) and B2C (Business-to-Citizen) services to rural populations.

The key benefit of e-terminals and kiosks is their ability to provide convenient, 24/7 self-service options, reducing wait times and the need for a large number of human staff. They are a critical component of the Digital India vision, bringing services closer to the public.

4.2.5 Hardware Specifications for Modern Tablets and Smartphones

The hardware specifications for tablets and smartphones have advanced significantly. The following tables provide a general overview of typical mid-to-high-end devices, reflecting current market standards as of 2024.

Tablet Hardware Specifications

Hardware Component	Description
CPU (Central Processing Unit)	High-performance 64-bit SoC (System on a Chip). Examples include the Apple M1/M2 series, Qualcomm Snapdragon 8 series, or MediaTek Dimensity series. CPUs now often have multiple cores (e.g., 8-core) and a Neural Engine for AI tasks.
RAM (Random-Access Memory)	Typically, 8 GB to 16 GB LPDDR5 RAM. Modern RAM is more power-efficient and faster than older standards.
Storage	128 GB, 256 GB, 512 GB, or 1 TB NVMe flash storage. This provides much faster read and write speeds than the older flash memory mentioned.
Display	Liquid Retina or OLED display with high resolution (e.g., 2732 x 2048 pixels for a 12.9-inch screen). Features like Pro-Motion (up to 120Hz refresh rate) and P3 wide colour gamut are common for a smoother and more vibrant visual experience.
Cameras	Main Camera: 12 MP or higher with features like Ultra-Wide lens and 4K video recording. Front Camera: 12 MP or higher with features like Center Stage for video calls.
Battery	Non-removable lithium-ion polymer battery. Battery life is typically 9-12 hours of typical usage. Fast charging and wireless charging are now standard features.
Connectivity	Wi-Fi 6/6E, Bluetooth 5.0+, and optional 5G cellular connectivity. USB-C or Thunderbolt ports are common for data transfer and charging.

Smartphone Hardware Specifications

Hardware Component	Description
CPU (Central Processing Unit)	High-end SoCs like the Qualcomm Snapdragon 8 Gen 3, Apple A17 Bionic, or MediaTek Dimensity 9000. These are multi-core processors with integrated GPUs and AI engines.
RAM (Random-Access Memory)	Typically 8 GB, 12 GB, or 16 GB LPDDR5 RAM.
Storage	128 GB, 256 GB, 512 GB, or 1 TB NVMe flash storage. Many phones have no expandable storage (no microSD card slot).
Display	6.1-inch to 6.8-inch OLED or LTPO display with high resolution (Quad HD+ or higher). Features like high refresh rates (120Hz or more) and HDR10+ support are standard.

Cameras	Multi-camera setups are now the norm, including a main sensor (50 MP+), an ultra-wide lens, a telephoto lens, and often a macro lens. Features include 4K/8K video recording, Pro mode, and advanced computational photography.
Battery	Non-removable lithium-ion polymer battery (typically 4,000 to 5,000 mAh). Fast wired charging (e.g., 65W or 100W) and wireless charging are standard.
Durability	IP68 rating for dust and water resistance is a common feature on high-end models.
Connectivity	5G, Wi-Fi 6E/7, Bluetooth 5.3, and NFC for contactless payments.

4.2.6 Apps and Related Services

The term "app" is a shortened form of "application," a software program designed to perform a specific function.1 Apps are fundamental to the functionality of modern digital devices.

Understanding App Ecosystems

Apps are developed for specific operating systems, meaning an app designed for Apple's iOS cannot be directly installed on a device running Google's Android. Each ecosystem has its own centralized digital marketplace, which serves as the primary and most secure source for downloading apps.

- Google Play Store: The official marketplace for Android apps.2 It's the most common and extensive app store in the world.
- Apple App Store: The exclusive marketplace for iOS and iPadOS apps. It is known for its stringent review process, which ensures a high level of quality and security.

While many apps are free, they are often monetized through in-app purchases or advertisements.3 The process of downloading, installing, and managing apps has been streamlined and is largely intuitive, guided by the app store interface.

Types of Apps

Apps are highly diverse and can be found for nearly every purpose imaginable.

- Productivity: Google Workspace (Docs, Sheets, Slides), Microsoft Office 365, Notion.
- Communication: WhatsApp, Telegram, Signal, Microsoft Teams.
- E-Commerce & Finance: Amazon, Flipkart, Myntra, BHIM, PhonePe, Paytm.
- Entertainment: YouTube, Netflix, Spotify, various gaming apps.4
- Government Services: UMANG, DigiLocker, MyGov.

App Management

The content's lengthy, step-by-step guides on how to install, close, or uninstall apps are no longer necessary as these functions are now core, intuitive parts of a mobile OS. Modern operating systems handle background app management automatically to optimize performance and battery life.5 For security, it's strongly recommended to avoid installing apps from "unknown sources" as mentioned in the original text, as this can introduce malware and security risks.

Apps by the Government

The Government of India's e-Gov AppStore is a repository of reusable and configurable applications designed to accelerate the development and deployment of e-governance solutions across various government departments and states. Its primary goals are to avoid duplication of effort, reduce costs, and ensure the availability of verified, standard-compliant applications. This initiative, part of the larger Digital India program, aims to deliver government services efficiently to citizens through digital platforms.

Here are some examples of key utility apps and digital platforms launched by the Indian government, categorized by sector.

1. Comprehensive Government Service Platforms

These platforms act as a single-access point for a wide range of government services, simplifying the citizen's interaction with various departments.

- UMANG (Unified Mobile Application for New-age Governance): This flagship app provides a single platform to access over 1,200+ government services, ranging from central to state-level ministries. It's a one-stop-shop for services like filing income tax, booking an LPG cylinder, checking provident fund details (EPFO), applying for a passport (Passport Seva), and more.
- MyGov: A unique citizen engagement platform that allows people to participate directly in governance. It facilitates discussions, polls, and surveys on policy formulation, and citizens can provide feedback and suggestions to various ministries.

2. Health and Wellness

- Aarogya Setu: Initially launched as a contact-tracing app during the COVID-19 pandemic, it has evolved into a national health application. It offers services like Ayushman Bharat Health Account (ABHA) creation, discovery of nearby hospitals, real-time blood availability information from eRaktKosh, and self-assessment tests.
- e-Hospital (Hospital Management Information System): A workflow-based ICT solution for public hospitals. It covers major functional areas like patient care, laboratory services, and electronic health record management.

3. Agriculture & Rural Development

- e-NAM (e-National Agriculture Market): This pan-India electronic trading portal networks existing agricultural markets (APMCs) to create a unified national market for agricultural commodities. It benefits farmers by providing them with more market options and transparent price discovery.
- Unified Portal for Agricultural Statistics (UPAg): An advanced data management platform that provides near real-time information on crop production, market trends, and pricing. It helps farmers, researchers, and policymakers make informed decisions.
- Kisan Suvidha: An app that provides farmers with crucial information on weather forecasts, market prices, plant protection, and dealer-related information for fertilizers and pesticides.

4. Education & Skill Development

- SWAYAM (Study Webs of Active-Learning for Young Aspiring Minds): This platform offers free online courses from Class 9 to post-graduation, covering various disciplines. It aims to provide accessible, high-quality education to all.
- e-Pathshala: A portal and app that provides digital educational resources like textbooks, audio, and video content for students, teachers, and parents.
- National Digital Library of India (NDLI): A project that creates a virtual repository of learning resources, offering a single-window search facility for a vast collection of academic and literary content.

5. Government Assistance & Identity Management

- DigiLocker: This app is part of the Digital India program and provides a secure cloud-based platform for storing and accessing authentic digital documents and certificates. Citizens can fetch and store documents like driving licenses, vehicle registration certificates, and educational mark sheets, which are considered legally valid.
- mAadhaar: An official app by the Unique Identification Authority of India (UIDAI) that allows users to carry their Aadhaar information on their smartphone. It provides services like downloading the e-Aadhaar, locking/unlocking biometrics, and generating a Time-based One-Time Password (TOTP) for secure authentication.

4.2.7 E-Services and Digital Transformation

E-services are services delivered through electronic means, leveraging internet connectivity to provide benefits in various sectors.11 The growth of these services is a direct result of increasing broadband penetration and the proliferation of smart devices.

- E-Education (eLearning): Online platforms and apps like BYJU'S, Coursera, and the government's SWAYAM program provide access to educational content, courses, and certifications for learners of all ages.

- E-Commerce: Online shopping platforms have transformed retail, allowing consumers to buy products from anywhere and sellers to reach a global market.12 The Open Network for Digital Commerce (ONDC) is a new government-backed initiative in India aimed at creating a more open and inclusive e-commerce ecosystem.13
- E-Health (Telemedicine): The use of digital technology to deliver healthcare services.14 This includes online consultations, remote monitoring of patients, and maintaining digital health records. The government's Ayushman Bharat Digital Mission (ABDM) aims to create a national digital health ecosystem.15
- E-Governance: The use of ICT to improve the efficiency and transparency of government services.16 The UMANG app and DigiLocker are prime examples of this, offering a centralized platform for citizens to access various government services.

4.2.8 Broadband and its Applications

Broadband is high-speed internet access that is "always on" and provides a reliable connection. It is the fundamental backbone for all e-services and digital devices to function effectively.

- **Broadband Technologies:**
  - Fiber-optic: The fastest and most reliable technology, using light signals over thin glass fibers.
  - Cable: Uses coaxial cables, often shared with television services.
  - DSL (Digital Subscriber Line): Uses traditional copper telephone lines.
  - Wireless: Includes cellular networks (4G, 5G) and satellite internet, crucial for connecting remote areas.

The growth of 5G technology is a significant advancement, promising much higher speeds and lower latency, which will further transform industries like telemedicine, smart cities, and autonomous vehicles. The government's BharatNet project is a key initiative to provide high-speed fiber broadband connectivity to every village, ensuring that the benefits of digitization reach all of India.

Notes

UNIT 4.3: Monitoring & Maintenance of Electrical Systems

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the fundamental principles and various types of electrical systems.
2. Understand the functions, classifications, and practical applications of batteries, power banks, and Uninterruptible Power Supply (UPS) systems.
3. Identify and implement critical electrical maintenance procedures and safety protocols to ensure a safe working environment and equipment longevity.

4.3.1 Electrical Systems & Principles

An electrical system is a network of interconnected components designed to generate, transmit, distribute, and utilize electrical energy for a specific purpose. These systems range from the simple circuitry inside a flashlight to the vast and complex power grids that span continents. Understanding their core principles is crucial for both safe operation and effective maintenance.

Grounding: The Cornerstone of Electrical Safety

Grounding is the practice of connecting an electrical circuit or a piece of equipment to the earth, which acts as a vast, common reference point. While often misunderstood, its primary purpose is not to make a circuit functional but to ensure safety. A proper ground provides a low-resistance path for stray electrical currents to flow safely to the earth, preventing them from causing harm to people or damage to equipment.

- Protection of Personnel: In the event of an electrical fault, such as a wire touching a metal casing, the ground connection quickly routes the excess current away from the equipment's exterior. This surge in current is detected by overcurrent protection devices like circuit breakers or fuses, which then trip and cut off the power supply, preventing a potential electric shock.
- Equipment Protection: Grounding helps to stabilize the voltage within a system. This protection is especially vital during events like lightning strikes or power surges, as it provides a path for the high voltage to dissipate into the ground, safeguarding sensitive electronics from destruction.

Electrical Hazardds

Working with electrical systems, even low-voltage ones, carries inherent risks. The most common hazards include:

- Electric Shock: This occurs when a part of the human body completes an electrical circuit. The severity depends on the voltage, the amount of current, and the duration of exposure. Even low currents can be fatal if they disrupt the heart's rhythm.
- Arc Flash/Blast: This is a sudden, explosive release of electrical energy. It can occur when high-voltage current jumps through the air between two conductors. The resulting flash is incredibly hot and bright, capable of causing severe burns, blindness, and even death, along with a powerful pressure wave that can cause physical trauma.
- Fire: Electrical fires are a significant risk. They can be caused by overloaded circuits, short circuits, or damaged insulation. As a wire heats up, it can ignite surrounding flammable materials, leading to a fire.

4.3.2 Power Supply & Backup Solutions

Batteries & Power Banks

A battery is a device that stores chemical energy and converts it into electrical energy through an electrochemical reaction. This makes them ideal for providing portable and off-grid power.

- Types: The most common types of modern rechargeable batteries are Lithium-ion (Li-ion) and Lithium-polymer (Li-po). They are favoured for their high energy density, low self-discharge rate, and relatively lightweight design, making them ubiquitous in devices like smartphones, laptops, and electric vehicles.
- Power Banks: These are portable, self-contained units that use rechargeable batteries to charge other mobile devices. They feature a sophisticated circuit that regulates power flow, preventing overcharging and short-circuiting.

Uninterruptible Power Supply (UPS)

An Uninterruptible Power Supply (UPS) is a critical piece of equipment designed to provide continuous, clean power to sensitive electronics. It acts as a protective buffer between the utility power and the equipment, safeguarding against power failures, surges, sags, and other electrical anomalies.

- Functionality: A UPS contains a battery, a battery charger, and an inverter. It constantly monitors the incoming power line. If the power supply falls outside a safe range (due to an outage, brownout, or surge), the UPS instantly switches to its internal battery, providing a seamless power transition.
- Types:
  - Standby UPS: This is the most basic and affordable type. It operates primarily on utility power and only switches to battery power when a complete outage is detected.
  - Line-Interactive UPS: This type can regulate voltage fluctuations without switching to battery power, providing better protection against power sags and surges.
  - Online UPS: This is the most advanced and reliable type. It constantly converts incoming AC power to DC to charge its battery, and then converts it back to clean AC power to supply the connected equipment. This "double-conversion" process ensures there is zero transfer time during a power outage.

4.3.3 Electrical Maintenance & Safety

Effective maintenance and strict adherence to safety protocols are paramount to prevent electrical accidents and extend the life of equipment. This involves a proactive approach to identifying and mitigating risks.

Electrical Safety Precautions

- Verify De-Energized Circuits: Never work on a circuit that is live. Always use a voltage tester or multimeter to confirm that the power is off before touching any wires or components.
- Use Insulated Tools: Always use tools with insulated handles when working on or near electrical systems. This provides a crucial layer of protection against electric shock.
- Inspect Equipment Regularly: Routinely check power cords, plugs, and outlets for signs of damage, such as frayed insulation, cracked casings, or discoloured components, which may indicate overheating.
- Avoid Wet Conditions: Water is highly conductive. Never handle electrical equipment with wet hands, and avoid using electrical tools in damp or wet environments.
- Utilize Personal Protective Equipment (PPE): When working with electrical systems, proper PPE is non-negotiable. This includes insulated rubber gloves, safety goggles, and non-conductive footwear.

Maintenance Procedures

- Preventive Maintenance: This is key to preventing failures before they occur. It includes cleaning dust and debris from panels and equipment, tightening loose connections, and checking for signs of stress or wear.
- Troubleshooting: When an issue arises, use diagnostic tools to pinpoint the problem. For example, a multimeter can measure voltage, current, and resistance to help identify a faulty component.
- Professional Assistance: Do not attempt to repair complex electrical systems yourself unless you are a certified and qualified electrician. Many systems require specialized knowledge and equipment to be serviced safely.
- Training and Awareness: All personnel should be trained to recognize electrical hazards and understand the proper safety procedures. This includes knowing where circuit breakers are located and what to do in case of an electrical incident.

By combining diligent maintenance practices with a strong safety culture, organizations can create a secure environment and ensure the reliable operation of their electrical systems.

Notes

UNIT 4.4: Revenue Management and Record Maintenance

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the core principles of revenue management within the CSC framework.
2. Describe the process of payment collection in CSC operations.
3. Outline the key documentation practices followed in CSC services.
4. Discuss the role and responsibilities of a Village Level Entrepreneur (VLE) in the CSC ecosystem.

4.4.1 Revenue Management and Record Maintenance

At the end of this module, you'll be able to understand the core principles of revenue management, payment collection, and documentation within the Common Service Centre (CSC) framework. You'll also learn about the role of a Village Level Entrepreneur (VLE) in this system.
The Common Service Centre (CSC) scheme is a crucial part of the Digital India program, aiming to deliver government-to-citizen (G2C) and business-to-citizen (B2C) services to rural and remote populations. The Village Level Entrepreneur (VLE) is the operator of the CSC, serving as the interface between the government/private service providers and the citizens.

Role of the VLE

The VLE is an entrepreneur at the grassroots level who operates the CSC to provide a wide range of digital services. Their responsibilities extend beyond simply providing services; they are central to the financial and administrative health of the operation.

- Service Delivery: The VLE provides a variety of services, including government form submissions, bill payments, and financial services.
- Revenue Management: A key responsibility is to handle all financial transactions, including collecting payments for services, issuing receipts, and maintaining financial records.
- Marketing: VLEs are responsible for marketing the available e-services to the local population, promoting digital literacy, and ensuring the community understands the benefits of using these platforms.
- Site Management: This includes managing the CSC's physical site, maintaining equipment, and handling administrative tasks like rent and electricity bill payments.

Benefits of the CSC Model

The CSC model addresses significant challenges faced by citizens in accessing services, particularly in remote areas. It replaces fragmented, manual, and often inefficient processes with a streamlined digital system, offering:

- Accuracy and Transparency: Digital records and standardized processes reduce human error and minimize opportunities for corruption.
- Convenience: Citizens no longer need to travel to distant government offices, wait in long queues, or navigate complex manual procedures.
- Centralized Control: The CSC system is centrally managed, ensuring standardization of services and processes across different districts and states, which was a major limitation of older systems.
- Financial Inclusion: By offering digital payment services and banking facilities, CSCs promote financial inclusion and help transition rural economies towards a cashless system.

4.4.2 Revenue and Record Management System

The CSC system is designed to provide a robust framework for financial operations and documentation.
Application and User Management
The modern CSC platform is a centralized, web-based application that provides VLEs with a single, integrated interface for all services.

- Prepaid System: Most CSC services, such as submitting an online form or paying a bill, operate on a prepaid system where the VLE deposits funds into their account with CSC SPV (Special Purpose Vehicle). As services are provided, the corresponding fees are deducted from the VLE's account. This system ensures financial discipline and simplifies revenue tracking.
- Dynamic Services: The platform allows for the dynamic creation of new services, ensuring that the CSCs can quickly adapt to new government initiatives or market demands without requiring extensive software changes.
- User Management: The system includes a sophisticated user management module that tracks all stakeholders, including VLEs, supervisors, and state coordinators. It maintains records of credit limits and transaction history for each VLE.

Integration and Payments
The CSC platform is built on a foundation of seamless integration with various external systems.

- Payment Gateways: The platform integrates with major payment gateways like BHIM, UPI, and internet banking, enabling VLEs to accept a variety of digital payments from customers.
- Third-Party Integration: The system is integrated with external service providers, such as telecom companies (for recharges), insurance providers, and utility companies, allowing VLEs to offer a wide range of services from a single portal.
- API-based Services: Many government services are delivered through APIs (Application Programming Interfaces), ensuring a real-time, digitized workflow for services like issuing digitally signed certificates, land records, or application forms.

4.4.3 Documentation and Compliance

Accurate record-keeping is a mandatory requirement for every VLE. It ensures transparency, helps in dispute resolution, and is crucial for financial audits.
Documentation Standards
The VLE must maintain both physical and digital records.

- Digital Records: All transactions, payments, and service usage are automatically recorded in the central CSC system. The VLE can access and download these records, which serve as the primary source of truth.
- Physical Records: The VLE must maintain physical copies of key documents. This includes customer details for certain services, rental agreements for the CSC site, and paper receipts for cash transactions.
- Standardized Formats: The CSC system provides standardized formats for receipts, transaction logs, and agreements to ensure consistency and ease of auditing.

Compliance and Ethical Conduct

- Data Protection: VLEs handle sensitive personal data, so they must follow strict data protection measures. All customer information must be handled ethically and kept confidential. This includes using secure passwords for their systems and not sharing personal details with unauthorized parties.
- Financial Compliance: The VLE must adhere to all financial regulations, including timely payment of rent and electricity bills for the site. Maintaining a clear audit trail of all transactions is essential to avoid financial irregularities.
- Customer Service: The VLE is often the first and only point of contact for the community. Providing excellent customer service, including effective conflict resolution and complaint handling, is vital for building trust and ensuring the long-term success of the CSC.

Exercise

Short Questions:

1. What is the purpose of the CSC 2.0 scheme launched in 2015?
2. Name two types of broadband technologies used in India.
3. Why is grounding important in electrical systems?
4. Mention two benefits of using CSCs for rural citizens.

Multiple Choice Questions:

1. What is the primary role of a Common Service Center (CSC)?
   a) Manufacture telecom devices
   b) Deliver government and commercial digital services to rural areas
   c) Provide internet services directly to urban households
   d) Build mobile towers
2. Which of the following is NOT a type of service offered by CSCs?
   a) Government-to-Citizen (G2C) Services
   b) Business-to-Citizen (B2C) Services
   c) Business-to-Business (B2B) Services
   d) Personal Software Development
3. What does UPS stand for in the context of electrical systems?
   a) Universal Power System
   b) Uninterruptible Power Supply
   c) Ultimate Power Storage
   d) User Personal Server
4. Which of the following is an example of a government digital service platform?
   a) Netflix
   b) Amazon
   c) UMANG
   d) Flipkart

Fill in the Blanks:

1. The CSC scheme is a part of the _____ program of the Government of India.
2. The individual responsible for operating a CSC at the village level is called a _____.
3. An app used for storing authentic digital documents and certificates is called _____.
4. A portable unit that stores energy and charges mobile devices is known as a _____.

Notes

5. Sustainable Practices in Telecom Infrastructure Management

Telecom Sector Skill Council

Unit 5.1 - Managing Hazardous and E-waste at Telecom Sites

Unit 5.2 - Adopting Green Energy and Resource Efficiency

Unit 5.3 - Following Waste Reduction Strategies

Unit 5.4 - Ensuring Compliance with Environmental Regulations

TEL/N9109

Key Learning Outcomes

By the end of this module, the paricipants will be able to:

1. Categorize, store, and dispose of hazardous materials and e-waste from telecom sites.
2. Apply green energy solutions and optimize resource efficiency at telecom facilities.
3. Employ effective strategies to reduce, reuse, and recycle waste across operations.
4. Adhere to all relevant environmental laws and regulations for telecom sites.
5. Identify and mitigate environmental risks associated with telecom site operations.

UNIT 5.1: Managing Hazardous and E-waste at Telecom Sites

Unit Objectives

By the end of this unit, the participants will be able to:

1. Identify, segregate, and categorize different types of e-waste and hazardous waste.
2. Follow all applicable regulations for the disposal and recycling of hazardous materials and e-waste.
3. Implement safe handling procedures to protect yourself and the environment.
4. Maintain proper records and documentation for all waste management activities.

5.1.1 Waste Identification, Segregation, and Categorization

Managing waste at a telecom site starts with correctly identifying and separating materials into their proper categories. This is crucial for both compliance and safety.

1. E-Waste (Electronic Waste):

E-waste consists of discarded electrical and electronic equipment. At a telecom site, this includes devices and components that no longer have a use.

- Categories:
  - Outdated/Non-functional Equipment: Servers, routers, switches, and other networking hardware.
  - Cables and Wires: Discarded copper or fiber-optic cables.
  - Mobile Devices: Old cell phones, modems, and their accessories.
- Segregation: E-waste should be stored in designated, separate bins or containers away from regular trash. This prevents contamination and ensures it can be sent to an authorized e-waste recycler.

2. Hazardous Waste

This category includes materials that pose a threat to human health or the environment if not handled correctly.

- Categories:
  - Lead-Acid Batteries: Commonly used in UPS systems and as backup power. These batteries contain lead and sulfuric acid, which are highly toxic.
  - Lithium-ion Batteries: Found in modern telecom equipment and power banks. They can be a fire hazard if damaged and contain hazardous components.
  - Diesel and Lubricant Residues: Fuels and oils from diesel generators. These are flammable and can contaminate soil and water.
  - Chemicals: Cleaning agents, solvents, and other chemicals used for maintenance.
- Segregation: Each type of hazardous waste must be placed in a clearly labelled, leak-proof container. Never mix different types of hazardous waste, as this can cause dangerous chemical reactions. For example, batteries must be stored separately in specialized containers.

5.1.2 Disposal, Recycling, and Safety Procedures

The correct disposal of waste is governed by strict regulations to minimize environmental harm.

- E-Waste Management Rules, 2022 (India): These rules make producers of electronic goods responsible for their end-of-life recycling. As a user, you must hand over e-waste only to authorized recyclers or dismantlers registered with the Central Pollution Control Board (CPCB). You cannot sell e-waste to unorganized scrap dealers. The rules also introduce a Producer Responsibility Organization (PRO) model, where producers are obligated to collect and recycle a certain percentage of their products.
- CPCB Hazardous Waste Regulations: The CPCB's regulations specify that hazardous waste must be disposed of at an authorized Common Hazardous Waste Treatment, Storage, and Disposal Facility (TSDF). Waste generators must obtain a one-time authorization from their State Pollution Control Board and ensure proper packaging and labelling before transport.
- Recycling: The goal is to recover valuable materials like lead, copper, and precious metals from waste. Recycling batteries, for example, is critical for recovering lead and preventing toxic runoff.

Safe Handling Procedures

Safety is non-negotiable when dealing with hazardous materials.

- Personal Protective Equipment (PPE): Always wear appropriate PPE.
- Gloves: Chemical-resistant gloves (e.g., nitrile) are essential when handling batteries and chemicals.
- Safety Goggles/Face Shield: Protect your eyes from chemical splashes.
- Respiratory Mask: Use a mask if there is a risk of inhaling fumes.
- Apron/Coveralls: Protect your skin and clothing from spills.

- **Handling Batteries:**
  - Lead-Acid: Never tilt a lead-acid battery, as the sulfuric acid can leak. Lift them with a battery strap or a proper lifting device.
  - Lithium-ion: Handle with care to avoid punctures or damage, which can cause them to overheat and catch fire. Store them away from heat sources.
  - Spill Response: Have a spill kit with absorbent materials readily available to contain and clean up spills of diesel, oil, or chemicals.

5.1.3 Record-Keeping and Documentation

Proper documentation is a legal requirement and is crucial for transparency and accountability.

Logs and Records of Disposed Waste

- Waste Manifest: For every batch of hazardous waste sent for disposal, a waste manifest (a multi-part document) must be completed. This manifest tracks the waste from its point of origin to its final destination at a TSDF.
- Logbook: Maintain a detailed logbook at the telecom site. This log should record:
  - The type and quantity of waste generated.
  - The date of segregation and disposal.
  - The name of the authorized recycler or TSDF.
  - The transport vehicle's details and driver's signature.
- Digital Records: Keep digital copies of all manifests, receipts from recyclers, and authorization letters for easy access during audits by regulatory bodies. This ensures a clear audit trail and demonstrates compliance with all waste management regulations.

Notes

UNIT 5.2: Adopting Green Energy and Resource Efficiency

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the importance of energy efficiency and resource conservation in telecom infrastructure.
2. Implement techniques to optimize power usage, reduce waste, and minimize fuel consumption.
3. Support the integration of renewable energy sources and hybrid power systems at telecom sites.

5.2.1 Introduction

The Green Imperative in Telecommunications

The telecommunications industry is a significant consumer of energy and resources. The constant demand for faster data speeds and wider network coverage requires a vast infrastructure of data centers and mobile towers, all of which consume substantial amounts of electricity. This consumption not only contributes to high operational costs but also to a large carbon footprint.

Adopting green energy and resource efficiency practices is no longer just an option; it's a strategic necessity. By embracing these principles, telecom operators can reduce costs, enhance sustainability, and comply with environmental regulations. This unit explores the practical steps you can take to make telecom operations more efficient and environmentally friendly.

5.2.2 Energy Optimization in Telecom Infrastructure

Energy consumption is a primary concern for telecom sites. A significant portion of this energy is used to power active equipment and cooling systems. By optimizing these, we can achieve substantial savings and environmental benefits.

Power Usage Optimization through Energy-Efficient Equipment

- LED Lighting: Switching from traditional fluorescent or incandescent bulbs to LED (Light Emitting Diode) lighting is a simple yet highly effective measure. LEDs consume up to 80% less energy, have a much longer lifespan, and generate less heat, which in turn reduces the load on cooling systems.
- Smart Cooling Systems: Cooling telecom equipment is a major power drain. Traditional air conditioning systems run constantly, regardless of the actual temperature. Smart cooling systems use sensors to monitor equipment temperature and automatically adjust their operation to maintain an optimal environment. This can include:
    - Free Cooling: Utilizing ambient air to cool the equipment when the outside temperature is low enough.
    - Precision Cooling Units: These units are designed to cool specific racks or areas, focusing the cooling efforts where they are needed most, rather than cooling the entire site.

Adopting Solar and Hybrid Energy Systems

Reliance on conventional energy sources can be costly and unreliable. Integrating renewable energy is a key strategy for enhancing a site's sustainability and resilience.

- Solar-Powered Telecom Towers: Solar panels are becoming increasingly common at telecom towers, especially in remote areas where grid connectivity is poor. The panels convert sunlight into electricity, which is used to power the site's equipment.
- Hybrid Energy Systems: To ensure uninterrupted power supply, solar power is often integrated with other energy sources.

A hybrid system typically combines solar power with a battery backup and a Diesel Generator (DG) set. During the day, solar energy charges the batteries and powers the site. At night or on cloudy days, the battery provides power. The DG set only runs when both solar and battery power are insufficient, significantly reducing fuel consumption.

Minimizing Fuel Consumption in DG Sets

Diesel Generators are a critical component of a telecom site's backup power strategy, but their use is a major source of operational cost and carbon emissions.

- Load Balancing: Ensuring that the DG set operates at or near its optimal load is crucial for fuel efficiency. An underloaded DG set consumes more fuel per kilowatt-hour of electricity generated. By consolidating loads or using smart controllers, you can ensure the DG runs efficiently when active.
- Regular Maintenance: A well-maintained DG set is a fuel-efficient DG set. Regular checks of the air filter, fuel injectors, and lubrication system prevent unnecessary fuel consumption and prolong the equipment's lifespan.
- Monitoring: Using a fuel management system to monitor fuel consumption and DG run time helps identify inefficiencies and schedule maintenance proactively.

5.2.3 Resource Efficiency and Waste Reduction

Beyond energy, the telecom industry also generates a significant amount of waste, particularly from cabling and equipment.

Structured Cabling and Cable Reuse

- Structured Cabling: This is a standardized approach to cabling a building or a site. Instead of a chaotic web of wires, structured cabling organizes cables into a logical, hierarchical system. This reduces waste during installation and makes it easier to manage, troubleshoot, and upgrade the network in the future.
- Cable Reuse: Damaged or obsolete cables often contain valuable materials like copper and plastic. Instead of discarding them, they should be properly segregated for recycling. Some cables, if undamaged, can be repurposed for other applications, minimizing the amount of waste sent to landfills.

Techniques for Energy Optimization

Energy efficiency is a key pillar of sustainable telecom operations.

- Smart Cooling: As mentioned, this involves using intelligent systems that adjust cooling based on real-time temperature data, rather than running at full capacity continuously. This can result in significant energy savings.
- Hybrid Power Systems: Integrating renewable energy sources like solar and wind with traditional backup power (batteries, DG sets) is an effective way to reduce reliance on the grid and minimize fossil fuel consumption.
- High-Efficiency Equipment: When purchasing new equipment, prioritize those with high Power Usage Effectiveness (PUE) ratings. A lower PUE indicates a more energy-efficient data centre.
- Load Management: Implementing software that can put idle network equipment into low-power or standby mode during off-peak hours can lead to substantial energy savings across the entire network.

The shift towards green energy and resource efficiency in the telecom sector is essential for both environmental sustainability and financial viability. By adopting energy-efficient equipment, integrating solar and hybrid power systems, and meticulously managing resources like fuel and cabling, individuals and organizations can play a pivotal role in building a more sustainable and resilient digital future. These practices not only reduce operational costs and carbon emissions but also position the industry as a leader in corporate social responsibility.

Notes

UNIT 5.3: Following Waste Reduction Strategies

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain best practices for minimizing packaging and cable waste.
2. Implement strategies for water conservation, including rainwater harvesting and wastewater reuse.
3. Promote sustainable site design to optimize resource utilization.

5.3.1 Waste Management and Resource Optimization

Introduction:

A Holistic Approach to Sustainability

In the modern telecommunications industry, sustainability goes beyond just energy efficiency. A comprehensive approach to waste reduction is essential for minimizing environmental impact, reducing operational costs, and adhering to corporate social responsibility goals. This unit focuses on practical strategies for managing and reducing waste from packaging, cables, and water resources, ensuring that every aspect of a telecom site's operation is optimized for sustainability.

Effective waste management involves not just proper disposal but, more importantly, reduction and reuse at the source.

Reducing Packaging Waste

Telecommunications equipment comes with a significant amount of packaging, including cardboard boxes, plastic wrap, and foam inserts. Reducing this waste is a crucial step towards sustainability.

- Promoting Reuse: Instead of discarding packaging after a single use, it should be carefully stored and reused whenever possible. For example, large cardboard boxes and foam inserts can be repurposed for shipping old or faulty equipment back to a central warehouse or a recycling facility.
- Supplier Collaboration: Encourage suppliers to use minimal and recyclable packaging. Choosing vendors that offer reusable crates or bulk shipping options can dramatically reduce waste at the site level.
- On-site Segregation: Immediately segregate packaging materials into dedicated bins for cardboard, plastics, and other materials to ensure they are properly collected and sent for recycling.

Promote Structured Cabling to Reduce Cable Waste

Structured cabling is a standardized, organized approach to wiring a telecom site or a data center. Unlike a disorganized "spaghetti" of wires, structured cabling uses a systematic layout with standardized components.

- Minimizing Waste: A structured approach ensures that the correct length of cable is used for each connection, eliminating the excess waste that results from cutting and discarding unnecessarily long cables.

- Optimizing Resource Utilization: It makes it easier to track and manage cable inventory, ensuring that resources are used efficiently.
- Ease of Maintenance: A well-organized cabling system simplifies troubleshooting and upgrades. This reduces the time and effort needed for maintenance, minimizing potential damage to cables and equipment.
- Best Practices: Use color-coding and clear labelling to identify different cable types and their destinations. This prevents confusion and reduces the risk of incorrect connections or accidental damage.

5.3.2 Water Conservation and Sustainable Site Design

Water is a critical resource used for cooling systems at many telecom sites. Implementing water conservation practices is essential for both environmental protection and operational efficiency.

Water Conservation Practices

- Rainwater Harvesting: This practice involves collecting and storing rainwater from the roofs of buildings or other surfaces. The collected water can be used for non-potable purposes, such as cooling systems, cleaning, and gardening. Implementing a rainwater harvesting system can significantly reduce the site's reliance on municipal water supplies.

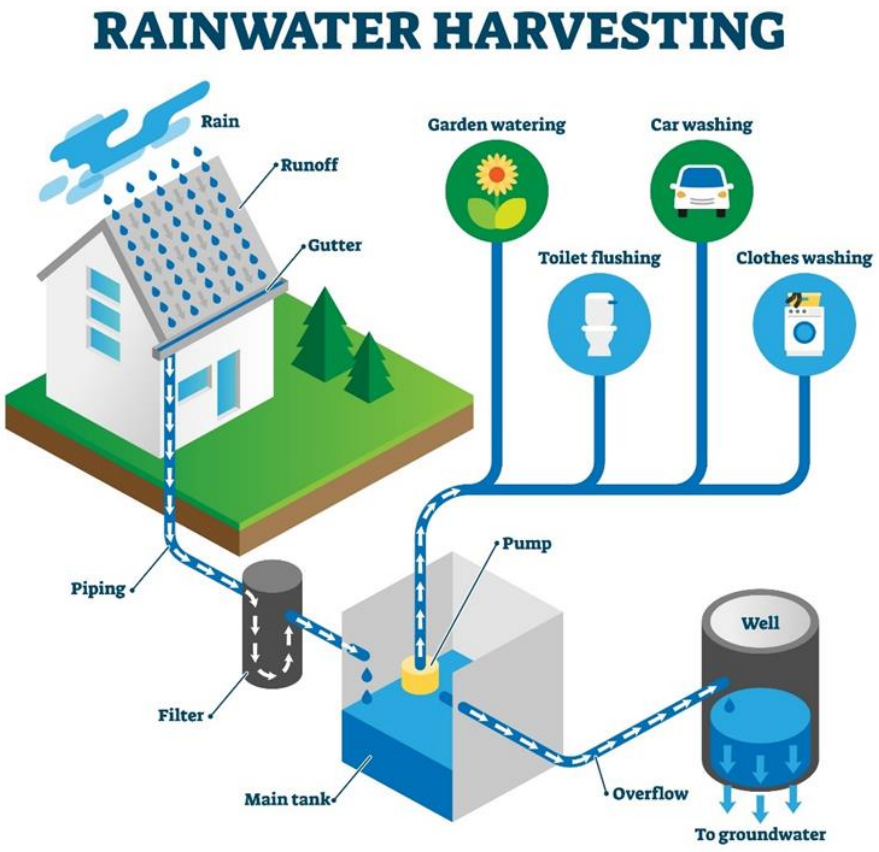


Fig 5.3.1 Rainwater Harvesting

- Wastewater Reuse: Wastewater from cooling towers or other systems can often be treated and reused. Installing a small, on-site water treatment plant can filter and purify the water, allowing it to be recycled back into the cooling system. This closed-loop approach drastically reduces water consumption.

Principles of Water Conservation and Sustainable Site Design

- Water Conservation: The core principle is to reduce, reuse, and recycle. This involves not only implementing harvesting and reuse systems but also using water-efficient cooling technologies, such as dry coolers, which use air instead of water for heat dissipation.
- Sustainable Telecom Site Design: Modern telecom site design incorporates sustainability from the ground up. This includes:
    - Efficient Cooling: Designing sites that use natural ventilation and smart cooling systems to minimize the need for water-based cooling.
    - Renewable Energy Integration: Including space for solar panels or other renewable energy sources in the initial design.
    - Waste Management Zones: Creating dedicated, clearly labelled zones for segregating different types of waste, as well as areas for storing materials to be reused.

Waste reduction and resource efficiency are integral to the long-term sustainability of the telecommunications industry. By proactively managing packaging and cable waste through reuse and structured cabling, and by conserving water through practices like rainwater harvesting and wastewater reuse, telecom professionals can make a significant positive impact. These strategies not only lead to cost savings and operational efficiency but also contribute to a greener, more responsible, and more resilient infrastructure. Adopting these practices demonstrates a commitment to environmental stewardship and positions the telecom sector as a leader in sustainable development.

Notes

UNIT 5.4: Ensuring Compliance with Environmental Regulations

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain and follow Central Pollution Control Board (CPCB) guidelines for waste disposal.
2. Assist in conducting environmental audits to verify compliance.
3. Educate and guide co-workers on eco-friendly practices and waste management policies.

5.4.1 Following CPCB Guidelines and Environmental Audits

Introduction: The Legal and Ethical Imperative

The telecommunications industry, like all others, has a legal and ethical obligation to protect the environment. Governments and regulatory bodies, such as the Central Pollution Control Board (CPCB) in India, have established strict guidelines to manage waste, control pollution, and promote sustainable practices. Non-compliance can lead to severe penalties, including hefty fines and legal action. This unit focuses on the critical role you play in ensuring your site not only follows these regulations but also fosters a culture of environmental responsibility.

Compliance with regulations is a non-negotiable part of modern telecom operations. It requires a systematic approach to waste management and regular verification of practices.

CPCB Guidelines for Waste Disposal

The CPCB has a clear set of rules for managing different types of waste generated at telecom sites, primarily focusing on Hazardous Waste and E-Waste.

- Hazardous Waste: This includes materials like used lead-acid batteries from UPS systems and diesel residues from generators. The CPCB's Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, mandate that such waste must be stored separately in leak-proof containers and disposed of only at an authorized Common Hazardous Waste Treatment, Storage, and Disposal Facility (TSDF). A waste manifest, a legal document tracking the waste from the site to the TSDF, must accompany every consignment.
- E-Waste: The E-Waste Management Rules, 2022, make it mandatory for producers, bulk consumers (like telecom operators), and refurbishers to manage their e-waste responsibly. You must ensure that all discarded electronic equipment, such as old routers, cables, and servers, is handed over only to a CPCB-authorized dismantler or recycler. Selling e-waste to informal scrap dealers is a violation of these rules.

Periodic Environmental Audits

An environmental audit is a systematic process of verifying that a site's operations are in compliance with all applicable environmental laws and internal policies.

- Audit Preparation: When an audit is scheduled, you'll be required to prepare all relevant documents, including waste manifests, disposal records, training logs, and inventory of hazardous materials.
- On-site Verification: The auditor will physically inspect the site to check for proper waste segregation, storage, and labelling. They will also assess your water and energy consumption records.
- Continuous Improvement: An audit is not just about finding faults; it's an opportunity for improvement. By assisting in the audit process, you gain valuable insights into areas that need attention, allowing you to proactively implement better practices.

5.4.2 Training and Awareness

A culture of compliance is built on a foundation of knowledge and shared responsibility. Your role extends beyond personal actions to include guiding your co-workers.

Guiding Co-workers on Eco-Friendly Practices

You serve as a key resource for your team. Regularly share knowledge about the importance of environmental responsibility and the specific policies that apply to your site.

- Waste Segregation: Reiterate the importance of separating trash from e-waste and hazardous materials. Use visual aids and clear labels on bins to make the process easy to follow.
- Energy and Water Conservation: Encourage simple habits, such as switching off lights and equipment when not in use and reporting any water leaks immediately.
- Proper Handling: Remind colleagues to use appropriate Personal Protective Equipment (PPE) when handling hazardous materials and to report any spills or accidents promptly.

The Importance of Employee Training

Training and awareness are the cornerstones of successful environmental compliance.

- Risk Mitigation: Trained employees are less likely to make mistakes that could lead to environmental damage or legal non-compliance.
- Legal Requirement: Many environmental regulations require companies to provide their employees with specific training on waste handling and safety protocols.
- Cultural Shift: Regular training fosters a sense of personal responsibility and collective commitment to environmental stewardship. It transforms compliance from a mere obligation into a core value of the organization.

Exercise

Short Questions:

1. Why is it important to separate hazardous waste into clearly labelled, leak-proof containers at telecom sites?
2. Name two energy optimization practices that help reduce power consumption at telecom infrastructure sites.
3. What is the purpose of structured cabling in telecom infrastructure management?
4. Describe one strategy for water conservation at telecom sites.
5. What role does a telecom worker play in ensuring environmental compliance?

Multiple Choice Questions:

1. What is e-waste in the context of telecom sites?
   a. Only used mobile phones
   b. Discarded electrical and electronic equipment such as servers, routers, cables, and mobile devices
   c. Any plastic packaging used in telecom equipment
   d. Only outdated cables
2. Which organization provides guidelines for hazardous waste management in India?
   a. TRAI
   b. CPCB (Central Pollution Control Board)
   c. ISRO
   d. Ministry of Finance
3. What is the main advantage of using structured cabling at telecom sites?
   a. It eliminates the need for power supply
   b. It organizes cables systematically, reduces waste, and simplifies maintenance
   c. It makes cables waterproof
   d. It increases energy consumption
4. Rainwater harvesting at telecom sites is mainly used for:
   a. Drinking water supply
   b. Non-potable purposes such as cooling systems and cleaning
   c. Power generation
   d. Watering public gardens

Fill in the Blanks:

1. The E-Waste Management Rules, _____ (year), require e-waste to be handed over only to authorized recyclers or dismantlers.
2. A hybrid energy system at a telecom site combines solar power, battery backup, and a _____ generator set.
3. Personal Protective Equipment (PPE) used for handling hazardous materials includes gloves, goggles, respiratory masks, and _____.
4. A waste manifest is a multi-part document used to track hazardous waste from the point of origin to the _____.

Notes

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6. Employability Skills (30 Hours)

Telecom Sector Skill Council

It is recommended that all training include the appropriate. Employability Skills Module. Content for the same can be accessed https://www.skillindiadigital.gov.in/content/list

DGT/VSQ/N0101

7. Annexure

Annexure I - QR Codes –Video Links

Annexure-I

QR Codes –Video Links

Module No.	Unit No.	Topic Name	Link for QR Code (s)	QR code (s)
1. Role and Responsibilities of an Optical Network Terminal Technician	UNIT 1.1: Introduction to Telecommunications	Introduction to the Telecom Sec-tor in India	https://youtu.be/Cag-bc-bivtM	Introduction to the Telecom Sector in India
	UNIT 1.4: Electromagnetic Spectrum (EMS)	Electromagnetic Spectrum	https://www.youtube.com/watch?v=imQ0q4aVYns	Electromagnetic Spectrum
2. Maintaining Site Hygiene and Implement Security (TEL/N6226)	UNIT 2.1: Overview of Computer Networks	Overview of Computer Networks	https://www.youtube.com/watch?v=NbjBRANGs4s	Introduction to Computer Network
	UNIT 2.2: IP Addressing and Subnetting	IP Addressing	https://www.youtube.com/watch?v=P7g--FJdUXE	What is Logical or IP Addressing
	UNIT 2.3 : Configuring Network	Lead Acid Battery	https://www.youtube.com/watch?v=RMP-W2Oo2Kk	Configuring Network Connectivity

Module No.	Unit No.	Topic Name	Link for QR Code (s)	QR code (s)
3. Preventive Maintenance of Optical Network Terminal (ONT) Components (TEL/N6227)	UNIT 3.1: Fiber Optics Overview	1.1.1 Fundamentals of Optical Fiber and their Applications	https://www.youtube.com/watch?v=DkQjF54gy9w	
		1.1.2 Working Principle of Optical Fiber Communication System	https://www.youtube.com/watch?v=q6_q2IBm93o	
		1.1.3 Performances Parameters of Optical Fiber	https://www.youtube.com/watch?v=Cwu3pbmarqM	

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